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THE HEPATIC FLORA
OF THE WHITEWATER RIVER GORGE
JACKSON AND TRANSYLVANIA COUNTIES, NORTH CAROLINA,
OCONEE COUNTY, SOUTH CAROLINA

A THESIS

BY

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ABSTRACT

The Hepatic Flora of the Whitewater River Gorge Jackson and Transylvania Counties, North Carolina, Oconee County, South Carolina. (December 1986)

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Hepatics were collected from six different study sites throughout the Whitewater River gorge in the southeastern "embayment" region of the southern Appalachian Mountains. The hepatics were identified and their distribution patterns listed and discussed. Relative occurrences for each species collected were calculated for each study site. Substrate preferences were also noted for each species. The study sites yielded a large number of hepatic species whose distribution patterns varied from local to worldwide.

ACKNOWLEDGEMENTS

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I. INTRODUCTION

The southeastern Blue Ridge escarpment region of North Carolina is well known among botanists and plant ecologists for its phytogeographically important populations of vascular plants and bryophytes. In addition to its noteworthy vegetation, the area's climate is unique in the eastern United States.

Six rivers drain the Southeastern Escarpment. Their vegetation has been surveyed and is summarized by Cooper and Hardin (1970). In a study of the mosses from the Blue Ridge Province, Anderson and Zander (1973), concluded that of the six rivers in the escarpment region, the Whitewater River gorge contains "the largest number of bryophyte species of any comparable area along the Blue Ridge, and possibly in the entire Appalachian Highland." Anderson and Zander dealt exclusively with the moss species collected in this area. The hepatic flora of the region has not been thoroughly studied.

The Hepaticae, or liverworts, are included in the division Bryophyta, along with the hornworts and mosses

(Scagel et. al., 1965). The term "liverwort" is derived from the herbalists, who attributed curative properties for liver ailments to any organism thought to resemble a liver (Schofield, 1985). The liverworts are very small, dorsi-ventrally flattened plants which grow on a wide variety of habitats and form a large, yet usually unnoticed, part of the world's vegetation.

No fossil evidence exists that provides us with any indications of the exact age of the bryophytes (Anderson, 1971). These small, delicate land plants have left few good fossils. The first unquestionable bryophyte fossils date from the Upper Devonian and Carboniferous periods (Scagel et. al., 1965). The ancient fossils indicate that the primitive bryophytes were similar to many species living today. According to Schuster (1982) most, if not all, of the morphologically simpler families of hepatics existed by the end of the Paleozoic.

Although the bryophytes are of little commercial value, several well known bryologists (Anderson, 1972; Sharp, 1941; Schuster, 1957) agree upon their importance as indicators of past floras and environments. The bryophytes are able to persist in small rock crevices and microenvironments long after the large, vascular plants have been extinguished by various macroenvironmental changes (Sharp, 1972). Therefore, study of the bryoflora in a given area may be useful in interpreting the origins of that flora and environment as well as the relationships that exist between that particular flora and other floras throughout the world.

II. REVIEW OF THE LITERATURE

Each region of the Southern Appalachian Mountains is biologicially unique, and the whole area has considerable diversity, but the extreme southeastern slopes of the Blue Ridge, near the junction of North Carolina, South Carolina, and Georgia (Figure 1) are rich in relic and disjunct species of vascular plants, bryophytes and certain animal groups (Anderson & Zander, 1973). With the discovery of the Appalachian endemic, *Shortia galacifolia*, in the late 1800's, attention was focused on this region as an area of potential biological importance (Cooper & Hardin, 1970).

Vegetational studies have been carried out in most of the escarpment gorges, including studies from the Toxaway River gorge (Cooper, 1963), the Horsepasture River gorge (Rodgers, 1965), the Bearwallow Gorge (Mowbray, 1966), Bearcamp Creek (Rodgers & Shake, 1965), the Thompson River gorge (Rascine, 1966) and (Ware, 1973), the Chattooga River gorge (DuMond, 1970), Devil's Fork (Patton & Powell, 1965) and Estatoe Creek (Rodgers & Shiflet, 1970). Several other inventories of gorge floras are included in unpublished research reports that have been conducted

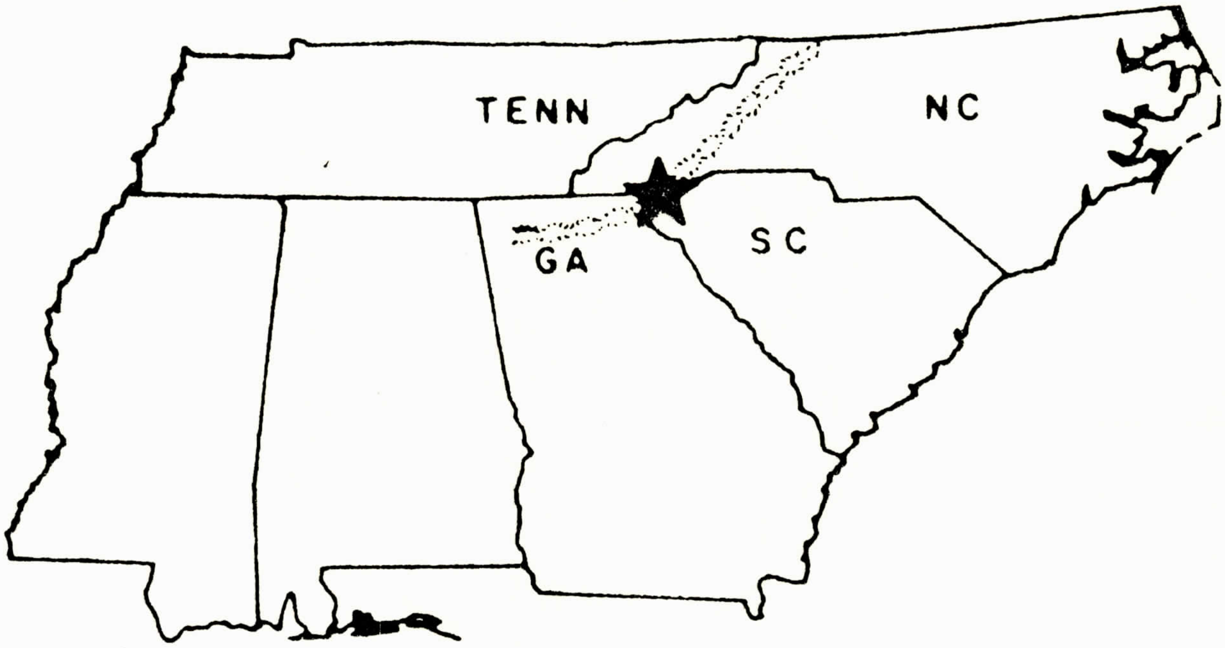

Figure 1. Escarpment Gorge Region of the Blue Ridge (Cooper & Hardin, 1970).

through grants from the Highlands Biological Station in Highlands, North Carolina. These studies, which are on file at the Highlands Biological Station include research on the fleshy fungi of the gorges by R. H. Patterson and C. T. Rogerson (1961), a study of the slime molds in the escarpment gorges by W. G. Fields (1966-67) and a survey of the lichen flora of the gorges by Barbara Moore (1964) and Alma Walker (1965). Farrar (1967) reports the collection of several tropical fern gametophytes from some of the gorges, and C. L. Rodgers and J. E. Green, Jr. have recently completed a booklet entitled "Botanical Survey of the Bad Creek Area, Oconee County, South Carolina" (1973). This booklet was a report of the study of the potential impact of one of Duke Power Company's proposed hydroelectric reservoirs on the flora of Oconee County, which is at the foot of the escarpment.

Several bryologists have collected mosses and liverworts from the Southeastern Escarpment gorges over the years. L. E. Anderson (1971) reports over 400 species of mosses from the Southern Appalachians. R. M. Schuster has collected many species of liverworts from the gorges which are cited in his 4-volume reference work, The Hepaticae and Anthocerotae of North America, East of the 100th Meridian (1966-1980). Such intense collecting has led to the discovery of a number of mosses and liverworts with interesting distributions.

Sharp (1939) has summarized the principal habitats available for bryophytes in the Southern Appalachians and emphasizes the great diversity of microhabitats and microclimates in that region. Billings and Anderson (1966) conclude that the southeastern escarpment gorge area receives heavy precipitation throughout the entire year, droughts are very rare, high temperatures are practically unknown, and minimum temperatures seldom go below freezing. The Blue Ridge "embayment" gorges appear to be unique in eastern North America in having a very moist climate combined with relatively mild winter and summer temperatures. Consequently, Schuster (1957) lists temperature, light intensity, and moisture as the most significant climatic factors in determining the distribution of hepatic flora.

Crum (1951, 1966, 1972) has pointed out that the bryophytes exhibit the same major phytogeographic patterns as higher plants, and that apparently these patterns have been determined by the same historical and biological influences. However, the ability of bryophytes to persist in tiny microhabitats makes them more accurate indicators than the vascular plants which are easily effected by changes in the environment (Anderson, 1963). Among the historical factors that have strongly influenced bryophyte distributions are the continental positions and the variation of climate through time, especially the most recent glaciations, and fluctuations in sea level (Schofield, 1985). The distribution patterns of many bryophytes support Braun's (1950) hypothesis that the southern Appalchians served as a center for the preservation of the Arcto-Tertiary flora which repopulated the eastern United States following the retreat of the Pleistocene glaciers (Anderson, 1971). When the data concerning current local and world distribution patterns is integrated with the past history of an area, particularly in the timing of past events and their favorability to the survival and expansion of restriction of floras, it is possible to speculate on the factors that led to the building of a flora (Schofield, 1985).

III. DESCRIPTION OF THE STUDY AREA

A. The "Embayment"

The term, Blue Ridge, is applied to the Appalachian Mountain ridge that extends southwest-northeast from northern Georgia to approximately the Susquehanna River in southern Pennsylvania (Anderson & Zander, 1973). The Whitewater River lies near the southeastern end of the Blue Ridge.

The escarpment divides the mountains of the Blue Ridge Province from the Piedmont. The crest of the escarpment forms the Eastern Continental Divide. In most sections of the Blue Ridge, the mountains rise sharply from the Piedmont, often as much as 518 meters or more in elevation in a distance of no more than three to five kilometers. However, on the northwestern border of South Carolina and the adjacent part of North Carolina, the upland peneplain is remarkably developed (Keith, 1907) and the rise from the Piedmont to the Blue Ridge Divide occurs in two distinct steps. The first makes an abrupt climb from 305 meters in the Piedmont up to 762 meters on the Piedmont Plateau. The second step is more gradual and occurs from the plateau to the Blue Ridge Divide with peaks over 1,463 meters (Figure 2). The mountains here are among the highest in the Blue Ridge.

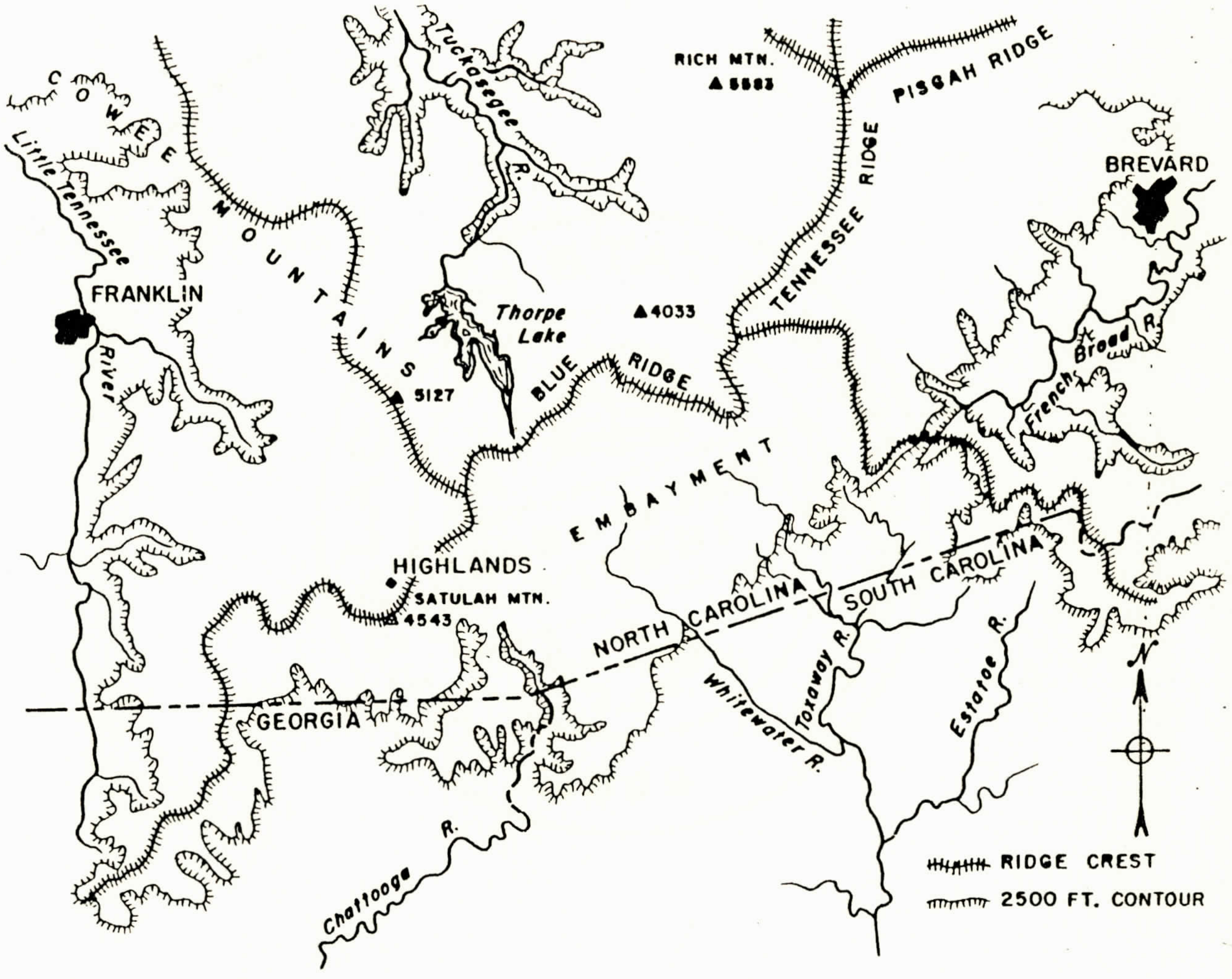

Figure 2. The "Embayment" of the Southeastern Escarpment Region of the Blue Ridge. (Map: Highlands Biological Station)

North of the Southeastern Escarpment region, the Blue Ridge forms the crest of the escarpment, however, in southwestern North Carolina near Hendersonville, the ridge turns to the west, leaves the escarpment, and follows another ridge for 48 or more kilometers to Highlands, North Carolina. The Blue Ridge here is not a ridge, but merely a divide at the edge of a faintly sloping plateau (Fenneman, 1938). The Blue Ridge rejoins the escarpment at Highlands and continues southwesterly approximately 64 more kilometers into northern Georgia, near Dillard in Rabun County. Here the Blue Ridge turns to the south and ends at the edge of the Great Appalachian Valley.

The irregular course of the Blue Ridge in the Southeastern Escarpment region, combined with the high mountain peaks to the north and the unusual two-step rise from the Piedmont up to these peaks, has produced a unique south facing, arc-shaped area, termed the "embayment" by Billings and Anderson (1966) (Figure 2). The "embayment" has Atlantic drainage and is about 45 kilometers wide from east to west and up to 14 to 16 kilometers deep from north to south (Billings & Anderson, 1966). The "embayment" includes portions of Macon, Jackson, and Transylvania counties in North Carolina and Oconee and Pickens counties in South Carolina.

Six rivers drain the "embayment" area (Figure 3). From northeast to southwest they are the Estatoe, Toxaway, Horsepasture, Thompson, Whitewater, and Chattooga. All of these rivers have their headwaters on some of the highest peaks along the escarpment. In addition, Billings and Anderson (1966) have concluded that the south-facing aspect of the "embayment" seems to entrap warm air masses from the south, producing orographic precipitation with annual totals that are among the highest in the eastern United States. This heavy rainfall creates a vast amount of runoff water which is collected in the rivers of the "embayment". The force of this extremely large volume of water flowing over the edge of the shelf-like plateau to the Piedmont below has produced deep, precipitous V-shaped river gorges.

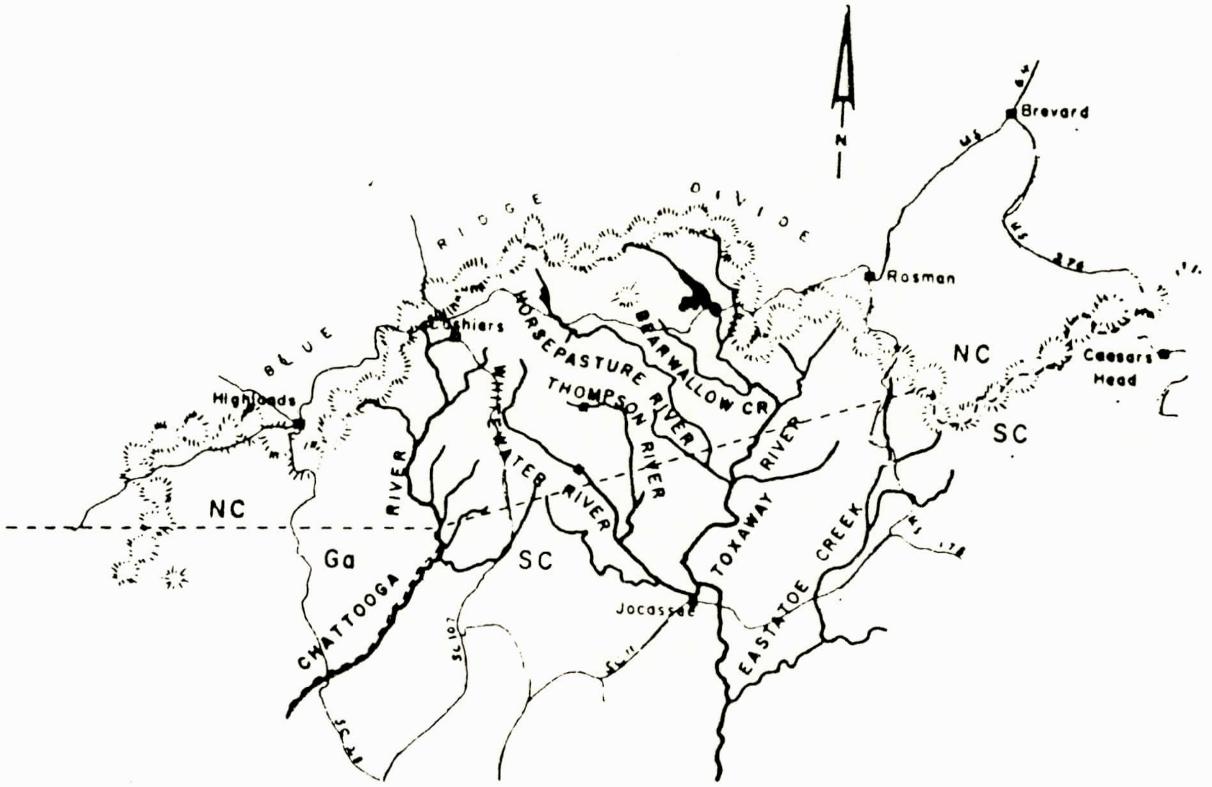

Figure 3. Rivers Draining the "Embayment".
(Cooper & Hardin, 1970)

B. The Whitewater River

Near the western edge of the "embayment", Little Whitewater Creek and Silver Run Creek originate and form the headwaters of the Whitewater River. These creeks emerge on the northeastern slope of Chattooga Ridge about 6.4 kilometers east of the Blue Ridge Divide.

Little Whitewater Creek originates below Terrapin Mountain at approximately 1,091 meters in elevation and flows approximately 1.4 kilometers northeast, turning southeast for 1.1 kilometers forming the western branch of the headwaters of the Whitewater River. Silver Run Creek has two tributaries, one originating near the top of Chimneytop Mountain at approximately 1,158 meters elevation. The other tributary emerges on Sassafras Mountain at approximately 1,210 meters elevation. These tributaries flow about 1.4 kilometers and join at approximately 1,057 meters forming Silver Run Creek.

Silver Run Creek flows southwesterly approximately 3.4 kilometers picking up another large tributary from the southwestern edge of Chattooga Ridge, before it merges with Little Whitewater Creek at about 975 meters elevation. Here, the Whitewater River is formed and flows in a southerly, then easterly direction (Figure 4). The river then turns to the southeast flowing toward the North Carolina state line. At this point, the river forms part

Figure 4. The Whitewater River.

of the boundary between southeastern Jackson and southwestern Transylvania counties in North Carolina. Eleven creeks or tributaries, including Happy Hollow Creek, Democrat Creek, and Waddle Branch join the Whitewater River during the journey from its origin to the edge of the Blue Ridge Escarpment. Here, at about 792 meters elevation, this large volume of water dramatically plunges vertically, 125 meters, forming the Upper Falls of the Whitewater River, the highest waterfall east of the Mississippi River (Figure 5).

Below the Upper Falls, Corbin Creek flows into the Whitewater from Transylvania County, North Carolina. Just over 0.9 kilometers below the base of the Upper Falls, the Whitewater River crosses the North Carolina state line and flows into Oconee County, South Carolina. Approximately 1.6 kilometers from the state line, and about 2.8 kilometers from the Upper Falls at approximately 548 meters elevation, the Whitewater makes its next descent into the Piedmont of South Carolina, forming the Lower Falls. This waterfall cascades over two rock ledges then flows 90 meters, over exposed rocks, to a spill basin cluttered with huge boulders and fallen trees. Approximately 0.6 kilometers from the base of the Lower Falls, at about 335 meters elevation, the Whitewater

Figure 5. The Upper Falls of the Whitewater River.

River makes its last descent over a series of cascades into Lake Jocassee in Oconee County, South Carolina.

The Whitewater River has carved a deep gorge in its descent from the edge of the escarpment to the Piedmont. The walls of the gorge are heavily wooded, rugged, and very steep. An extremely steep elevation gradient exists within the gorge. A difference of 457 meters in elevation exists between the Upper Falls at the edge of the escarpment plateau, and the foot of the escarpment where the Whitewater flows into Lake Jocassee. In addition, a variety of slope faces exist throughout the river gorge. This topographic variety provides a wide range of habitats that support a variety of bryophyte populations. The floor of the gorge is very rugged, and for the most part, cluttered with large boulders and fallen trees. A few areas along the river are somewhat leveled off and Anderson and Zander (1973) report that in one place the floor of the gorge formerly accommodated a small cultivated plot. The tree-lined banks of the river rise directly up from the rushing river to form a somewhat closed canopy. The dense canopy allows only intermittent to sparse sunlight during clear days. As one enters the gorge, the high humidity and somewhat cooler temperatures are noticed immediately.

The abundant vegetation, the waterfalls and numerous springs throughout the gorge, and the frequent precipitation common in the "embayment" area create a wide variety of microclimates and microenvironments. The various types and sizes of rocks, the various soil types, and the 57 different species of trees present in the gorge provide countless substrates for bryophyte populations. The "niches" or sites to which some species of bryophytes are restricted are the result of the interoperation of all these environmental and edaphic factors (Schuster, 1957).

C. Lake Jocassee

Lake Jocassee is a 31,567 square kilometer reservoir constructed between April, 1971 and December, 1973 by Duke Power Company at the foot of the Blue Ridge Escarpment in Oconee County, South Carolina (Figure 6). The six major rivers that drain the escarpment provide a 238 square kilometer watershed for the lake, which in turn, provides pumped storage capacity to the reversible turbo-generators of the Jocassee Hydroelectric station. The maximum elevation of the lake is 338 meters. At this elevation, the lake is backed up well into the lower ends of the Whitewater, Thompson, Horsepasture, and Toxaway River gorges. The lake has a surface area of 306 square kilometers with a volume of 1.4×10^{12} liters of water. The maximum depth of the lake is 107 meters and the average depth is 46.3 meters. A 117 meter concrete dam regulates the flow of the water from Lake Jocassee into Lake Keowee, also constructed by Duke Power Company. The primary purpose of these lakes is to provide cooling water for the Oconee Nuclear Station, located approximately 18 kilometers downstream from Lake Jocassee, and to provide water to turn the turbines of the Keowee Hydroelectric Station.

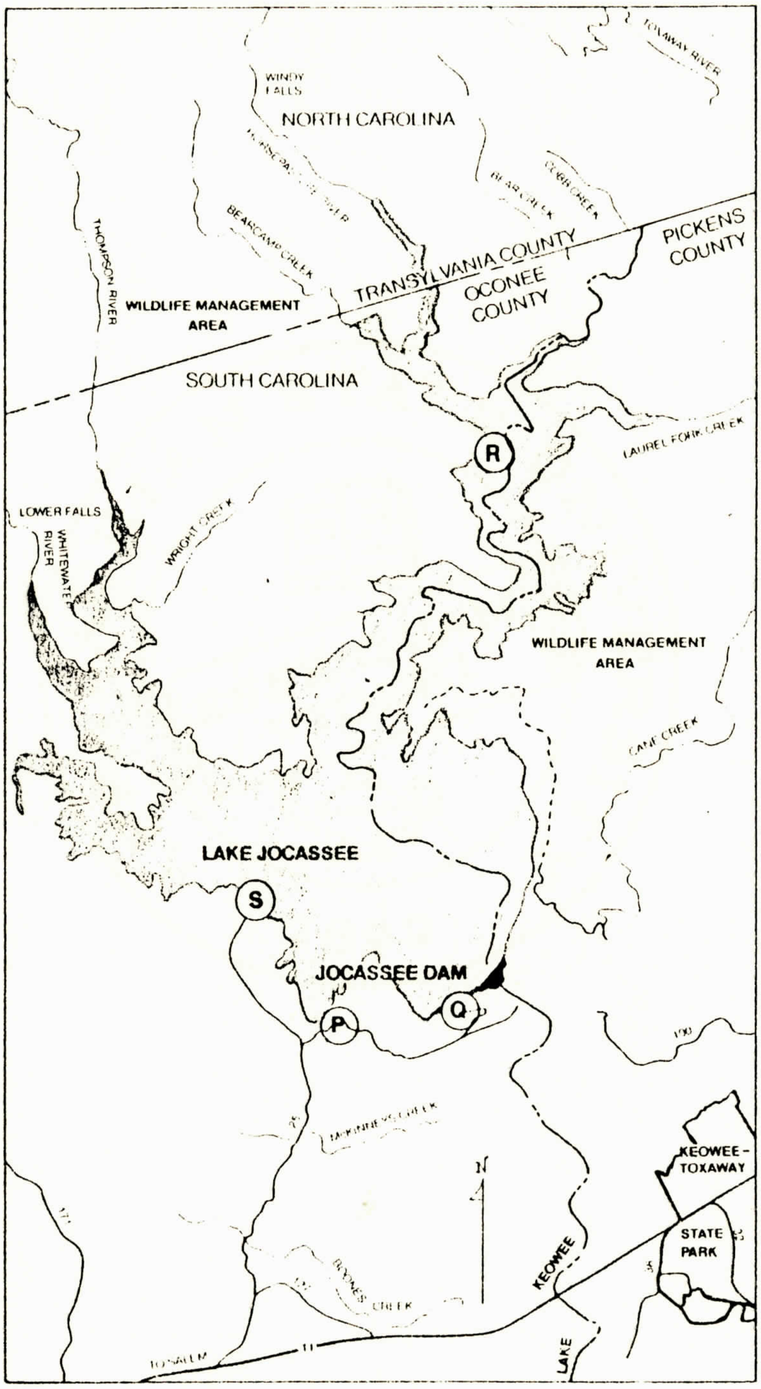

Figure 6. Lake Jocassee, Oconnee County, S. C.
(Map: Oconee Nuclear Plant Pamphlet)

Before the construction of Lake Jocassee, the Thompson River flowed into the Whitewater River near the foot of Hester Mountain, about 2.4 kilometers from the Lower Falls of the Whitewater. The Whitewater then continued southeastward approximately 6 kilometers past the town of Jocassee, the site of which is now covered by Lake Jocassee, and finally flowed into the Toxaway River on the border of Oconee and Pickens Counties, South Carolina, forming the Keowee River. The Thompson and Whitewater rivers now flow directly into Lake Jocassee. The possible impact, on the plant life, of the drowning of the lower ends of the "embayment" river gorges has been the concern of many botanists.

D. Geology

The Southern Appalachian mountains have undergone several periods of uplift since the Cretaceous. During this time, the southeastern Blue Ridge escarpment was formed. Two theories concerning the origin of the escarpment have been developed. According to Davis (1904), the escarpment was formed as a result of the diverse and extensive headwater erosion of the various streams that drain the area. Another, more recent, theory is that the escarpment is the result of faulting (White, 1950). White proposed that faulting occurred along the "Blue Ridge Border Fault" during the Triassic and once again in the late Tertiary and the fault zone was subsequently subjected to extensive differential erosion.

The entire southeastern escarpment area is underlain by igenous and metamorphic rocks deposited during the late Precambrian or early Paleozoic. Folding, metamorphism, and intrusion took place during the Taconic Orogeny at the close of the Ordovician and formed the complexes of granite, gneiss, and schist present in the escarpment region. These rocks lie in bands of varying width with a strike running roughly parallel to the orientation of the major portions of the Blue Ridge escarpment. The oldest of these rocks, micaceous schists, or the older Carolina

Gneiss, and amphibolites are present in the northern and western portions of this region. To the southeast, a narrow band of schistose rocks of the Brevard zone appears, as does a portion of the Henderson Gneiss (Cooper & Hardin, 1970).

The rugged nature of the Whitewater River gorge is due not only to the steep, heavily wooded sides of the gorge but to the great abundance of rock cliffs, sheer rock faces, and large boulders which are found throughout the gorge as well. Various complexes of gneiss, schist, and granite are evident throughout the gorge. The river, itself, is cluttered with mainly granite rocks and in some areas huge granite boulders clog the flow of water, forcing the river to re-route itself or flow over the boulders. Around the walls of the Upper Falls, there are small exposed areas of calcareous rocks, and near the Lower Falls there is an outcropping of limestone (Anderson and Zander, 1973).

Just as geological occurrences have led to the development of the southeastern escarpment, evidence indicates (Sharp, 1941; Schuster, 1969) the possibility that two major geologic events have played a very large role in the development of the present southern Appalachian flora. These events are continental drift and glaciation.

Briefly, the continental drift theory (Neill, 1970; Dott and Batten, 1976) proposes that over 250 million years ago, all the major continents of the world were fused into one super-continent called Pangaea. During the Triassic period, Pangaea began a split into northern and southern halves. This phenomenon would have separated some of the established distribution patterns of the plants and animals that populated the earth. For more than 150 million years, these two land masses remained intact but separate. During this long period extensive dispersal of the various biota continued on each of the sub-continents, possibly with some dispersal between the two along their adjacent shores. Around the close of the Meozoic era, the two sub-continents began a separation which yielded the seven continents that we recognize today. Schuster (1969) maintains that the distribution patterns of the hepatics strengthen the continental drift hypothesis.

Approximately one million years ago, glaciers began to develop in the Northern Hemisphere. Subsequently, ice sheets moved across Europe and Canada. The southern edge of the Canadian ice reached the northern United States and followed roughly a line from New York City, westward through Pennsylvania to the Missouri River basin to west-central Montana (Neill, 1970). The glaciers eliminated most of the vegetation in the regions they covered, along with much of the soil and underlying rocks.

The southern Appalachians have been continuously available for plant occupation for a very long period of time. These mountains had eroded to their present rugged features by the Pleiocene epoch (Broadhurst, 1951). The southern Appalachians are the oldest land mass unaffected by marine water or continental glaciation in eastern North America (Sharp, 1970). This particular area has not been covered by marine waters since the Paleozoic era and was not scoured by the Pleistocene glaciers. However, the colder temperatures brought on by the glacial advance caused many changes over the area covered by the glacier and those areas to the south of it.

E. Soils

The soils of the southeastern escarpment have not been used agriculturally very much and therefore have not been studied thoroughly. Walker (1964) has recognized eleven humus types in the Highlands-escarpment gorge region. The walls of the Whitewater River gorge are heavily wooded and covered by a thick layer of humus formed from leaf litter. Walker reports that the soils in the region were derived in part from crystalline rocks, gneisses, schists, and granites. The soils of the gorges are somewhat acidic and not particularly fertile. The higher elevations of the escarpment possess soils of the Gray-Brown Podzolic group. The soils of the valleys are Red-Brown Podzolics, which is evident in the Whitewater gorge region. The topsoil is usually brown to dark brown with a yellowish-brown to reddish brown subsoil. Topsoil, in most areas excluding the gorge walls, is from about 18 to 38 centimeters deep and the subsoil is 51 to 76 centimeters deep. Under the subsoil lies the decomposed granite, gneiss, and schistose parent material (Rodgers and Shake, 1965) which contributes to the somewhat rocky nature of the Whitewater River soils. Bedrock is frequently exposed at the surface, especially in the areas around the waterfalls, riverbed, springs, and the steep, open areas of the gorge walls. Extensive erosion is evident in many places throughout the Whitewater River gorge.

Lee (1955) concludes that the Potters-Ashe, Halewood, Hayesville, and Talladega-Ramsey associations comprise the major soil groups present in the area. Soil maps by Perkins, et al. (1948) show Porters loam predominating over the highlands and rough, stony, soil over Porters parent material in the river gorges. According to data collected by Losche (1967), the soils of the escarpment gorges possess characteristics of advanced weathering which suggests that they have undergone weathering quite rapidly.

F. Climate

The climate of the gorges of the southeastern Blue Ridge escarpment is characterized by high rainfall, moderate reliable temperatures and lack of extremes of heat and drought. It appears to be a climate unique to North America (Cooper & Hardin, 1970).

Extremely high annual precipitation totals are the most notable of the "embayment's" unique climatic characteristics. Thornthwaite (1931, 1948) classified the climate in western North Carolina as a Perhumid-Rainforest type climate (Mowbray & Oosting, 1968). According to Thornthwaite, western North Carolina is one of the few places where precipitation exceeds the potential evapo-transpiration resulting in excess water every month. In addition, data collected in several climatic studies (Billings & Anderson, 1966; Carney, 1960; Cox, 1923) indicates that the "embayment" itself receives considerably more precipitation per year than the Piedmont to the east and south or the mountains to the north (Billings & Anderson, 1966).

According to Cooper and Hardin (1970), the annual rainfall in the area has two peaks, one from December to March and the other from July to August. Precipitation is usually distributed evenly throughout the remaining months and no regional dry season has been noted. Continuous records for 18 years from the Highlands, North Carolina Weather Bureau Station, on the southwestern edge of the "embayment", indicate that the mean annual precipitation is 216.4 centimeters.

Billings and Anderson (1966) measured precipitation totals at five different stations within the "embayment" gorge area. Two stations were located within river gorges. One of these sites was near the base of the Upper Falls of the Whitewater River. Three other stations, set up outside the gorges were used for comparison. One was on a ridge above the Upper Falls, the second was on the escarpment plateau and a third just below the confluence of the Whitewater and Thompson Rivers at the foot of the escarpment plateau. Billings and Anderson's principal observation was that the two gorge stations usually showed higher precipitation totals for each measured period than any of the Weather Bureau Stations in the area. From their study, they concluded that an average of about 250 centimeters of precipitation per year is common for most areas on or near the escarpment in the "embayment" area.

According to Billings and Anderson (1966), physical characteristics of the "embayment" may contribute to the high precipitation levels in the area. The escarpment in this part of the Blue Ridge faces almost due south while north of the "embayment" it faces east. The southeastern escarpment receives precipitation due to the moist southerly air from the Gulf of Mexico. As the air moves northwest over the lowlands, it accumulates more moisture and upon reaching the hills of the upper Piedmont of South Carolina, the air rises, expands and rain clouds form. When this supermoist air reaches the east-west oriented escarpment, it is forced to rise, resulting in heavy orographic precipitation. The topography of the gorges may aid in this phenomenon by trapping the warm, moist air at the mouths of the gorges in the upper Piedmont and channeling it up to the heads of the gorges. More intense storms have been noted around the lower ends of the river gorges than at other places within the "embayment". Billings and Anderson (1966) recognize this as "the only south-facing escarpment or mountain range in eastern North America that rises directly up from the lowlands and is not a rainshadow."

This section of the escarpment forms a somewhat sunken, arc-shaped, feature in which the rim of the arc is formed by the high peaks of the Blue Ridge to the north. A shelf-like plateau lies below the rim and drops off rather abruptly to the Piedmont. The unusual two-step configuration and the "embayed" characteristic of the escarpment cause moist air to move up from the lower escarpment and become entrapped, which results in heavy, prolonged precipitation.

Thornthwaite (1941) compiled climatic maps of the "embayment" region. From these maps, he recognized the Blue Ridge "embayment" as the only area in the eastern United States where the "crop season" (March-August) was "superhumid", even during drought years. Drought is evidently rare in the "embayment" area (Billings and Anderson, 1966).

The moderate temperatures in the "embayment" are yet another contributing factor to the area's unique climate. Temperatures recorded from the "embayment" seem to exhibit a considerable amount of local variation which aids in sorting out the different plant communities within the area.

According to Billings and Anderson (1966) maximum and minimum temperatures at each of the five sites selected for their microclimatic studies indicated that air temperature near the base of the Upper Falls of the Whitewater River showed a consistently narrower range than any of the other study sites or Weather Bureau Stations in the area. Their measurements also indicated that the winter temperatures were warmer and the summer temperatures were cooler at this site than in the surrounding area and that the first frost comes later to the Whitewater River gorge than the other study sites or the surrounding area. The first killing frost in Brevard, approximately 34 kilometers away from the Whitewater, occurs around October 13 and Highlands usually gets its first frost around October 7. Data indicate (Cox, 1923) that the Whitewater River gorge receives its first killing frost after the end of October.

Temperature differences within the gorges are accentuated in the bryophyte layer. Data collected by Billings and Anderson (1966) from bryophyte mats in the Whitewater River gorge, showed very narrow temperature ranges. During the summer, bryophyte temperatures ranged from 9.4 to 19.4 degrees Celsius. The winter minimum was never below 1.6 degrees Celsius; however, only 6 meters away, the minimum air temperature was -8.3 degrees Celsius. Bryophyte layer temperatures from the ridge stations exhibited wider ranges than those in the gorges or on the escarpment plateau. Maximum bryophyte temperatures, measured by Billings and Anderson, on Whitewater Ridge above the Upper Falls were 15 to 30 degrees higher during the summer and 40 to 60 degrees higher during the winter than the maximum temperatures recorded in the Whitewater River gorge.

In general, the incidence of bryophytes is highest in environments with a relatively low amount of temperature variation (Schuster, 1957). Therefore, the hepatics, would be expected to be abundant within the "embayment" gorges where there is little change in the temperature seasonally.

G. Vegetation

According to Sharp (1941), during the Tertiary a relatively uniform vegetation extended from Canada to the highlands of Mexico and Central America, southeast to the area now composing the southern Appalachians. The present flora of the southern Appalachians has developed from this ancient flora. Sharp describes the ancient flora as a mixture of the north temperate flora and subtropical taxa. The north temperate flora, usually referred to as the Arcto-Tertiary forest, extended across Canada, southward into the north-central and northeastern United States, as well as across northern Europe (Neill, 1970). The subtropical taxa may have reached the region by migration from the south or these taxa could have been common to all the warmer areas of the Earth at that time.

During the Pleistocene epoch, the ancient flora of the southern Appalachians underwent some changes. As the glacial ice advanced, the Eurasian and North American segments of the Arcto-Tertiary forest fell back to the south (Neill, 1970). A few species of this old north temperate flora managed to survive in some scattered, isolated regions after the glaciers made their final retreat. The largest remnant of the Arcto-Tertiary forest, today, occupies the Sino-Japanese Province and is concentrated in Japan and China. The second largest remnant is located in eastern North America, with its concentration in the southeast and the Appalachian Mountains (Neill, 1970). The Arcto-Tertiary forest was composed of many species of trees, including maples, beeches, sycamores, ashes, alders, and basswoods. The Temperate Deciduous forest which predominates in the southern Appalachian region today, contains many of these same species. Fossil pollen studies by Cain (1944) indicate a possibility that many of the dominant tree species of the cove forests of the southern Appalachian gorges remained in the southeastern Blue Ridge region during the entire Pleistocene epoch. Braun (1950) developed and refined the idea that the southern Appalachians served as a center from which migration of the Arcto-Tertiary remnant species into glaciated and newly exposed land masses has taken place. Considering the arboreal specificity of many bryophytes along with the mild microtemperatures, constantly available moisture, and the protected nature of the Whitewater River gorge, it is possible that some bryophyte populations have persisted in this gorge for many years.

A complete survey of the vegetation of the Whitewater River gorge is not currently available. Rodgers and Green (1973) report 57 species of trees, 35 species of shrubs, 25 species of vines, 241 herbaceous species, 16 fern species, and 3 species of clubmoss from the Bad Creek area of South Carolina, which is only a few miles southwest of the Whitewater River gorge. Anderson and Zander (1973) report 285 species of mosses from the Whitewater River gorge. A list of the hepatics from this gorge was not available before this study.

In a synthesis of all the botanical studies done in the southeastern escarpment, Cooper and Hardin (1970) conclude that several broad vegetation units may be found throughout the gorge region. From observations made during this study, the author recognized five vegetational types within the Whitewater River gorge. These community types are:

1) "Riverbank Shrub Thicket Community" - forms the thick vegetation encountered along the river bank. The dominant tree in this community is the Alder, *Alnus serrulata*. Sweet Gum, *Liquidambar styraciflua* and Sycamore, *Platanus occidentalis* trees are common where the river widens and Sweet Birch, *Betula lenta*; Hemlock, *Tsuga canadensis*; and Tulip Poplar, *Liriodendron tulipifera* are more abundant along narrow sections of the river. Dense stands of Rhododendron, *R. maximum* are abundant in this community and several herbaceous species that are common to rich woods thrive there also.

2) "Disturbed Floodplain Forest" - is found in a few areas along the Whitewater River, usually below 549 meters. Here, rocky, sandy alluvial soil is common. Locally, White Pine, _Pinus strobus_; Tulip Poplar, _Liriodendron tulipifera_; and Hemlock, _Tsuga canadensis_ may become common species with a larger diversity of saplings and herbaceous species forming the understory and ground layer. The various successional plants occupying these areas would be expected to ultimately form a Mixed Mesophytic Forest.

3) "Mixed Mesophytic Forest" - is most common in the coves and on the lower slopes of the gorges, nearest the river. The coves are the most mesophytic areas in the gorge region, with small streams and springs that aid in producing a cool, humid environment. Coves may be dominated by any one or several species including Red Maple, _Acer rubrum_; Sweet Birch, _Betula lenta_; Beech, _Fagus grandifolia_; Tulip Poplar, _Liriodendron tulipifera_; Basswood, _Tilia heterophylla_; and Hemlock, _Tsuga canadensis_. Dogwood, _Cornus florida_ and Holly, _Ilex opaca_ form the understory and Rhododendron, _R. maximum_ and Dog Hobble are common along the edges of the small streams in the coves. Most of these woody species provide substrates for some of the epiphytic species of bryophytes. The herbaceous layer is exceptionally

rich and bryophytes may be closely associated with the streams. Below 670 meters, the forests of the gorge slopes exhibit characteristics of the more mesophytic coves combined with the Oak forests that are more common on the higher slopes. No species alone dominates in this particular community, however, Pignut and Mockernut Hickory, Carya glabra and C. tomentosa; Black Gum, Nyssa sylvatica; White Ash, Fraxinus americana; Chestnut Oak, Quercus prinus; and Black Oak, Quercus velutina commonly comprise the canopy but do not occur in the cove communities. Dogwood, Cornus florida and Sourwood, Oxydendrum arboreum are the dominant understory species. Several mesophytic species of shrubs and herbs mixed with a few xeric species make up the ground layer. Referring to a similar community in the Chattooga River Gorge, DuMond (1970) concludes that after logging, White Pine, Pinus strobus moves in as the dominant canopy species forming a "White Pine-Mixed Deciduous Forest."

4) "The Upland Oak Forest" - described by Braun (1950) as the Oak-Hickory-Pine community, is the most extensive forest community in the gorges of the escarpment. This forest type occupies the upper slopes of the gorges from 305 to 914 meters in elevation. A "Chestnut Oak Type" community dominates the slopes approaching 914 meters and on gradual east and north

facing slopes at lower elevations. Before the chestnut blight, an Oak-Chestnut community dominated most of the crest of the Blue Ridge in North Carolina. Now Chestnut Oak, Quercus prinus is a common dominant species and Red Oak, Quercus rubra and Tulip Poplar, Liriodendron tulipifera have replaced the Chestnut, Castanea. The most common associated species are Red Maple, Acer rubrum; Scarlet Oak, Quercus coccinea; Sourwood, Oxydendrum arboreum; White Oak, Quercus alba; Hickory Carya cordiformis; Black Oak, Quercus velutina; and Black Gum, Nyssa sylvatica. Stands of Sweet Birch, Betula lenta; Fraser Magnolia, Magnolia fraseri; Hemlock, Tsuga canadensis and dense thickets of Rhododendron, R. maximum and Mountain Laurel, Kalmia latifolia are frequent. Galax, G. aphylla is a common herb and a few bryophytes may grow on the bark of the trees and over rock outcrops throughout this community. The drier south and west facing slopes, usually below 762 meters in elevation, support a "Mixed Oak-Hickory Type Community." The presence of White Oak, Quercus alba as a dominant or codominant, with Chestnut Oak, Quercus prinus; Black Oak, Quercus velutina; and Scarlet Oak, Quercus coccinea as dominants or codominants and an increased amount of Hickory, Carya cordiformis, distinguishes this community type from the "Chestnut Oak Type." Red Maple, Acer rubrum; Black

Locust, Robinia pseudo-acacia; and Black Gum, Nyssa sylvatica, are also frequent understory species. Scarlet Oak, Quercus coccinea becomes dominant and several species of Pine occur more often on the drier south-facing slopes nearest the ridges. Mountain Laurel, Kalmia latifolia and Blueberry, Vaccinium corymbosum form most of the shrub layer. Few herbs or bryophytes thrive in this dry community.

5) "The Pine Dominated Community" - is formed by Pitch Pine, Pinus rigida; Virginia Pine, Pinus virginiana; and Shortleaf Pine, Pinus echinata which are scattered along the dry ridge tops with a well developed understory of hardwoods. This community takes on different forms, depending upon location, but is best developed on narrow ridges, exposed sites along the rims of the gorges, on southeasterly to southwesterly slopes and in areas where the soil is shallow. Different combinations of pines and hardwoods within this community form the "Pine Community Type" on the driest ridges below 855 meters and the "Pine-Oak Community Type" on the less xeric ridges. Pines are widely spaced above Black Gum, Nyssa sylvatica; Red Maple, Acer rubrum; Scarlet and Chestnut Oak, Quercus coccinea and Q. prinus in the "Pine Community Type." Scattered stands of Mountain Laurel, Kalmia latifolia, and Blueberry, Vaccinium corymbosum form the shrub layer. The

widely spaced trees allow a dense layer of herbaceous vegetation to develop. A few bryophytes may be found on rotting logs and the bark of some trees within this community type. The "Pine-Oak Community" occurs on less xeric ridges where the pines and oaks grow closer together, forming a more closed canopy than is found in the "Pine Community Type." The shrub layer is more continuous and fewer herbaceous species frequent this community type.

IV. MATERIALS AND METHODS

Field work for this study began in August, 1981. Six intermittent collections continued through September, 1982. United States Geological Survey topographic maps of the Whitewater River were studied to determine which areas within the river gorge would, collectively, yield a representative sampling of the species of liverworts to be found in the Whitewater River gorge. Because the distribution of bryophytes is influenced most by the interoperation of microenvironmental factors within an area, study sites were chosen using mainly elevation, topography, availability of moisture and accessibility as criteria. The areas were marked on topographic maps and each of the selected areas was thoroughly searched and specimens taken.

A. Study Sites

The majority of the liverworts reported in this study were collected from six study sites within the gorge. The study sites are listed in the descending order of their elevations within the gorge.

1. Corbin Creek - This study site is located in Transylvania County, North Carolina. The study area covers the ravine which has been carved in the side of the gorge by Corbin Creek from approximately 853 meters to 731 meters in elevation. The ravine is densly shaded, humid and protected by a dense thicket of vegetation. The creek flows down the steep, northeast slope of the gorge into the river just below the Upper Falls. Substrates included rocks in the creek and along the creek bank, the soil along the creek bank, roots of Rhododendron sp. bordering the creek and small pieces of decayed wood in the creek and on the creek bank.

2. Above the Upper Falls - This site is located in Jackson County, North Carolina at approximately 807 meters in elevation. Most collections were made along the west bank of the river approximately 50 meters from the crest of the Upper Falls. Habitats included a small, shaded spring which flowed over exposed rocks into the river above the crest of Upper Falls, as well as several wet shaded undercuttings that had been carved out of the river bank by the force of the swiftly flowing river. Substrates included mud, wet exposed roots of trees and shrubs, and rocks.

3. Western side of the gorge, adjacent to the Upper Falls - This study area is located in Jackson County, North Carolina. Collections were made from the trail which runs along the western rim of the gorge (approximately 792 meters), down through the forest, to the base of the Upper Falls (approximately 640 meters) elevation and around the base of the falls. Habitats included xeric to mesic forest communities near the rim of the gorge, a humid forest zone nearer the base of the falls and a spray zone at the base of the waterfall. Substrates included trees, rocks, rotting logs and stumps, and dry to wet soil.

4. Below the Upper Falls - Located in both Jackson and Transylvania Counties, North Carolina, this study site is approximately 0.8 kilometers down-river of the Upper Falls at approximately 609 meters elevation. Collections were made down the western side of the gorge, through a mesic forest to the river, along both sides of the riverbank, around islands of vegetation in the river, and from rocks in the river. Substrates included the vegetation mats covering rocks in the river, rocks, moist soil along the riverbank, and trees.

5. The Lower Falls - This study site is in Oconee County, South Carolina just over the North Carolina state line. Collections were made along the west bank to the river from the crest of Lower Falls (approximately 549

meters elevation), throughout the humid forest down to the base of the falls (approximately 366 meters elevation) and around the spill basin there. The base of the falls is protected by a dense tangle of vegetation. The area is shaded and very humid. The spill basin is cluttered with fallen trees and large boulders covered by a film of algae and bryophytes. Substrates included trees, rotting trees and stumps, rocks, and moist soil.

6. Lake Jocassee - Located in Oconee County, South Carolina approximately 0.8 kilometers below the Lower Falls, this study site encompasses the mouth of the Whitewater River at approximately 549 meters to 366 meters elevation. Here, the Whitewater River flows down over a series of rocks, forming a cascade, then flows into the northwestern arm of Lake Jocassee. Collections were made around the confluence of the river and Lake Jocassee. Many of the rocks in the river were covered by a film of bryophytes and algal growth similar to that at the Lower Falls. Specimens from these rocks were subjected to spray and splashes from the river. Substrates included the bark of trees, rock outcrops, and the river bank at the edge of the forest.

B. Collection and Identification

Most of the common methods of vegetative sampling are not suitable for the collection of bryophytes. This is due to their small size and to the fact that the bryophytes are dependent upon their microenvironments. Therefore, it was necessary to search out the microclimates and microhabitats within each study area using a random or selective method of sampling. Each study site was thoroughly investigated and any substrate or microhabitat that appeared to be suitable was closely checked and samples were taken.

Suitable microenvironments were found in a variety of locations including dry, shaded forests, sunny to shaded river and creek banks, islands of vegetation within the river, moist shaded coves, shaded rock outcrops, springs, and waterfalls. Substrates common in these areas included dry and wet rocks, dry and moist soil, bark on the bases and trunks of trees, exposed roots of shrubs and trees, rotting stumps and logs, ground litter, and grass. Samples ranged in size from small patches of a few shoots of one species to compact patches or clumps of bryophytes containing five or six species.

Field equipment included a small knife for scraping specimens from trees and rocks, a 10x hand lens, small paper bags in which to store the specimens, and a day pack to conveniently carry the specimens. Some of the samples were closely observed using the hand lens, and tentatively identified in the field. After collection and observation, the samples were placed in small paper bags. Information concerning the habitat, substrate, and approximate elevation of the collection was recorded on each bag. Samples were then taken to the laboratory for identification. Bryophytes dry rapidly, making identification of some species difficult. Specimens were checked and identified as soon as was possible after collection, usually within a week.

The keys used for the identification of the species were, The Liverworts of the North Carolina Mountains (Hicks, 1980), and The Hepaticae and Anthocerotae of North America, Volumes I-IV (Schuster, 1966-1980). How to Know the Mosses and Liverworts by Conard (1969) was also consulted several times.

After identification was complete, the specimens were placed in envelopes with herbarium labels. In addition to the name, herbarium labels included location, habitat, substrate, and elevation information. The packets were placed in Appalachian State University's Herbarium, located in the Biology Department.

V. RESULTS

A. A List of the Hepaticae of the Whitewater River Gorge

The following list includes 62 species of hepatics collected from the Whitewater River Gorge. Species not collected during this study but listed by Schuster (1966-1980) or represented by specimens previously collected by Hicks (1980) from the Whitewater River gorge are included in this checklist, for reference. These species are indicated by an asterisk (*) and the collector's name. The collection sites within the gorge, common substrates, elevation range within the gorge and collection number for each specimen is included for each species. Arrangement of orders, families, and nomenclature is based on Schuster's *Hepaticae and Anthocerotae of North America* (Schuster, 1966).

MARCHANTIALES

Conocephalaceae

Conocephalum conicum (L.) Lindb. Upper Falls and Lake Jocassee. On wet, dripping, shaded rocks. 1120-2500 feet. #63,66,163.

Marchantiaceae

Dumortiera hirsuta (Sw.) Nees Above the Upper Falls. Under a dripping rock ledge, on rocks and ground. 2600 feet. #111,112,121.

METZGERIALES

Aneuraceae

Aneura pinguis (L.) Dum. Upper Falls. On shaded, dripping rocks. 2500 feet. #65.

Riccardia chamedryfolia (With.) Grolle Lake Jocassee. On mud, rocks. 1150 feet. #44.

*Riccardia latifrons Lindb. Lake Jocassee, Oconee Co., S. C. On rocks below the Lower Falls, along a small tributary at the mouth of the river. 3-13-1979 (Hicks #8550), and Jackson Co., N. C. Over a rotting log receiving spray from the Upper Falls. 7-5-1979 (Hicks #9024).

Riccardia multifida L. S. Gray Upper Falls and Lake Jocassee. On wet ground, mud, moist rocks, soil. 1120-2650 feet. #91,93,160,201.

Dilaenaceae

Pallavicinia lyellii (Hook.) Carruth. Above the Upper Falls, Corbin Creek, Lake Jocassee. On wet spring and river banks. 1120-2700 feet. #106,113,201.

Pellia epiphylla (L.) Corda Lower and Upper Falls, Corbin Creek, Lake Jocassee. On wet river banks, ground litter, wet humus, mud, and rocks. 1200-2550 feet. #22,55,79,82,132,144,179,199.

Pellia neesiana (Gott.) Limpr. Above and Below the Upper Falls. Moist rocks. 2000-265- feet. #47,98.

Metzgeriaceae

Metzgeria conjugata Lindb. Upper Falls. Below Upper Falls, Lake Jocassee. Dry and damp rocks and moist soil. 1120-2350 feet. #36,51,53,88,167,176,187.

Metzgeria crassipilis (Lindb.) Evans Upper Falls and Lake Jocassee. River rocks, rock outcrops, bark of Dogwood. 1110-2450 feet. #56,68,71,83,151,158.

Metzgeria furcata (L.) Dum. Upper Falls. On moist rocks. 2300 feet. #78.

Metzgeria leptoneura Spruce Above the Upper Falls. Moist soil. 2600 feet. #111.

Metzgeria temperata Kuwah. Lake Jocassee. Shaded rock outcrop. 1175-1200 feet. #146,190,198.

JUNGERMANNIALES

Adelanthaceae

Odontoschisma denudatum (Nees) Dum. Above the Upper Falls. Moist soil. 2650 feet. #115.

Odontoschisma prostratum (Sw.) Trev. Above the Upper Falls, the Upper Falls, Lake Jocassee. On rotting wood, soil, base of *Rhododendron* sp. 1200-2650 feet. #90,92,94,97,103,105,138.

Blepharostomaceae

Blepharostoma trichophyllum (L.) Dum. Lower Falls. On soggy ground. 1300 feet. #17.

Calypogeiaceae

Calypogeia fissa (L.) Raddi Lower Falls, Corbin Creek, Lake Jocassee. Riverbanks, rocks, moist soil, humus. 1100-1760 feet. #8,116,122,130,143,144,166,167.

Calypogeia muelleriana (Schiffn.) K. Muell. Above Upper Falls, Corbin Creek, Upper Falls, Below the Upper Falls, Lower Falls. Soil, rocks, bark of an Oak, rotting wood, humus. 1250-2700 feet. #15,19,21,23,31,55,60,73,75,87,92,95,96,99,125.

**Calypogeia neesiana* (Mass. & Carest.) K. Muell. ex. Loeske Upper Falls, Transylvania Co., N. C. (Blomquist #11166).

Calypogeia peruviana Nees & Mont. Lake Jocassee. On moist rock. 1120 feet. #160. and below Lower Falls near Jocassee. 7-5-1979. (Hicks #8223).

Calypogeia sullivantii Aust. Lake Jocassee. Moist soil. #155.

Cephaloziaceae

Cephalozia bicuspidata (L.) Dum. Upper Falls, Lower Falls, Lake Jocassee. On soggy humus, soil over rocks, base of tree. 1140-2250 feet. #17,76,194.

Cephalozia connivens (Dicks.) Lindb. Corbin Creek, Below the Upper Falls, Lake Jocassee. Rotting wood, wet rocks, soil. 1200-2500 feet. #31,119,138,170.

Cephalozia lunulifolia (Dum.) Dum. Lower Falls. Humus. 1200 feet. #8.

Nowellia curvifolia (Dicks.) Mitt. Corbin Creek, Upper Falls, Lake Jocassee. Rotting wood and the root of Rhododendron sp. 1200-2800 feet. #67,109,118,123,128,138.

Frullaniaceae

Frullania brittoniae Evans Upper Falls. Bark of an Oak. 2400 feet. #64.

Frullania plana Sull. Corbin Creek, Upper Falls, Lake Jocassee. Moist and dry rocks, soil over rocks. 1180-2550 feet. #78,85,88,124,199.

Frullania squarrosa (R. B. N.) Nees Upper Falls and Lower Falls. Base of trees, dry rocks. 1800-2300 feet. #12,54,85.

Frullania tamarisci subsp. asagrayana (Mont.) Hatt. Lower Falls and Lake Jocassee. Bark of trees. 1180-1300 feet. #25,161.

Jubula pennsylvanica Steph. Evans Corbin Creek, Above the Upper Falls, Upper Falls, Below the Upper Falls, Lake Jocassee. Wet soil over rocks, wet and dry rocks, wet soil or humus. 1100-2680 feet. #35,37,40,41,48,49,52,89,111,114,127,131,136,144,147,149,151,158,167,172,187,196,197.

Gymnomitriaceae

Marsupella emarginata (Ehrh.) Dum. Below the Upper Falls, Lower Falls. Wet rocks. 1200-2000 feet. #3,5,42.

*Marsupella emarginata subsp. tubulosa (Steph.) Lower Falls near Jocassee, Oconee Co., S. C. (Anderson #8524 and Schuster #40952-1).

*Marsupella paroica Schust. Below Upper Falls. (Schuster #25009a).

*Marsupella sphacelta fo. media (G.) Schust. Upper Falls, Jackson Co., N. C. (Schuster #25021).

Herbertaceae

*Herberta adunca ssp. tenuis (Evans)Miller & Scott Between Middle and Upper Falls. (Schuster).

Jungermanniaceae

*Jamesoniella autumnalis (DeCand.) Steph. Below the Lower Falls, Oconee Co., S. C. (Schuster).

Jungermannia lanceolata L. Lake Jocassee. On moist rocks. 1120 feet. #149,160.

*Nardia lescurii (Aust.) Underw. Jackson and Transylvania Cos., N. C. and Oconee and Pickens Cos., S. C. (Taylor, 1939).

Solenostoma crenuliformis (Aust.) Steph. Corbin Creek, Below Upper Falls, Lower Falls, Lake Jocassee. Moist soil, wet rocks. 1050-2600 feet. #15,28,119,134,139,153,155,174,191,194.

*Solenostoma fossombronioides (Aust.) Schust. Lower Falls, near Jocassee, Oconee Co., S. C. (Anderson #8491).

Solenostoma gracillimum (Sm.) Schust. Corbin Creek, Lake Jocassee. Moist creek bank, wet soil over rocks. 1200-2700 feet. #113,179.

Solenostoma hyalinum (Lyell) Mitt. Below the Upper Falls. Wet rock outcrop. 2000 feet. #42.

Solenstoma obscurum (Evans) Mitt. Below the Upper Falls, Lower Falls, Lake Jocassee. Wet soil, mud on a rock, wet rocks. 1120-2000 feet. #6,27,178,185,192.

*Solenostoma pyriflorum Steph. Below the Upper Falls, Transylvania Co., N. C. (Schuster #40575) and below the Lower Falls, 3 miles north of Jocassee (Schuster #40955).

Lejeuneaceae

*<u>Cheilolejeunea</u> <u>evansii</u> (M. S. Tayl.) Schust. Jackson and Transylvania Cos., N. C. (Taylor, 1938), Below the Upper Falls, 2200-2300 feet, Jackson Co., N. C. (Schuster #40907), just above the mouth of the gorge (Schuster #32241), several points below the Lower Falls, Oconee Co., S. C. (Schuster #27838, 40923,20930,40900,40959.

*<u>Cheilolejeunea</u> <u>myriantha</u> (Nees & Mont.) Schust. Transylvania Co., n. C. (M. S. Taylor, 1938), Oconee Co., S. C. (M. S. Taylor,1938).

<u>Cololejeunea</u> <u>biddlecomiae</u> (Aust.) Evans Upper Falls and Below the Upper Falls. Bark of trees, decaying log. 2000-2250 feet. #32,86.

*<u>Cololejeunea</u> <u>cardiocarpa</u> (Mont.) Schust. Lower Falls, ca. 2 miles above Jocassee, Oconee Co., S. C. Epiphyllous.

<u>Drepanolejeunea</u> <u>appalachiana</u> Schust. Below the Upper Falls. On a dry rock. 2000 feet. #30.

<u>Harpalejeunea</u> <u>ovata</u> (Hook.) Schiffn. Lower Falls, Lake Jocassee. Bark of trees, rock crevices, soil over rocks. 1180-1400 feet #1,7,11,141,161,196.

<u>Lejeunea</u> <u>laetevirens</u> Nees & Mont. Lower Falls, Lake Jocassee. On wet and dry rocks. 1120-1200 feet. #141,145,152,164,165.

<u>Lejeunea</u> <u>lamacerina</u> ssp. geminata Schust. Below the Upper Falls, Lake Jocassee. Over rocks. 1120-2000 feet. #129,137.

<u>Lejeunea</u> <u>ruthii</u> (Evans) Schust. Lower Falls, Lake Jocassee. Rocks, bark of an Oak. 1200 feet. #7,140,198.

*Lejeunea ulicina subsp. bullata (Tayl.) Schust. Below the Lower Falls, above Jocassee, Oconee Co., S. C. (Schuster).

Lejeunea ulicina subsp. ulicina (Tayl.) Tyl. ex G. L. & N. Below the Upper Falls. Bark of Tulip Poplar tree. 2000 feet. #32.

Leucolejeunea clypeata (Schwein.) Evans Above and below the Upper Falls, the Upper Falls, Lower Falls, Lake Jocassee. Bark of trees, dry and wet rocks. 1100-2600 feet.
#1,7,9,10,11,13,16,20,24,26,44,46,62,100,101,133,135,137,140,141,147,148,159,169,171,181,182k,186,188,189,193,195,200,202.

*Leucolejeunea conchifolia (Evs.) Evs. Mouth of gorge, ca. 2.2 miles above Camp Jocassee (site now covered by Lake Jocassee). (Schuster #30011a,30013d) and Below the Lower Falls (Schuster #40962c, 40541d).

*Leucolejeunea unciloba (Lindenb.) Evs. Below the Upper Falls. (Schuster #40514d), Below the Lower Falls, north of Jocassee. (Schuster 40949b, 40939c), near the mouth of the gorge (Schuster 30013c).

*Rectolejeunea maxonii Evs. Approximately 5 kilometers northwest of Jocassee. 1200-1500 feet. (Schuster).

Lepidoziaceae

Bazzania trilobata (L.) S. F. Gray Above and below the Upper Falls, Lower Falls, Lake Jocassee. Rock outcrops, wet soil, decaying logs, soil at the base of trees. 1200-2650 feet. #14,43,45,97,103,105,170,176.

Microlepidozia sylvatica (Evans) Joerg. Above the Below the Upper Falls, Upper Falls, Corbin Creek, Lower Falls, Lake Jocassee. Soil, rocks, rotting wood. 1160-2700 feet. #4,8,33,92,102,107,113,130,155,170,180.

*Plagiochila caduciloba Blomquist Below the Upper Falls. Damp, shaded rocks. (Hicks #9017), below High Falls, Transylvania Co., N. C. (Schuster and Anderson), 4-5 miles northwest of Jocassee, Oconee Co., S. C. (Schuster).

*Plagiochila euryphyllon subsp. echinata (Schust.) H. Inoue Below the Upper Falls. Wet rocks. (Hicks #9036), Upper Falls, 2400 feet. (Schuster).

Plagiochila ludoviciana Sulliv. Below the Lower Falls, near Jocassee. (Schuster).

*Plagiochila ludoviciana Sulliv. Below the Lower Falls, near Jocassee. (Schuster).

Plagiochila sharpii Blomquist Below the Upper Falls. Over a dry rock. 2000 feet. #30.

Plagiochila sullivantii Gott. Lake Jocassee. Rock outcrop. 1175 feet. #165.

*Plagiochila sullivantii var. spinigera Schust. Collected once, from a deep, wet recess in the spray zone of the Upper Falls. (Schuster).

*Plagiochila undata Sulliv. South of the Lower Falls, ca. 3 miles north of Jocassee. (Schuster).

Plagiochila virginica var. caroliana Schust. Lower Falls. Over rocks. 1800 feet. #2.

Porellaceae

Porella pinnata L. Below the Upper Falls, Upper Falls, Lake Jocassee. Over wet rocks. 1120-2200 feet. #34, 61,175,182,183,184,195.

Porella platyphylla (L.) Pfeiff. Upper Falls, Lake Jocassee. Bark of trees, dry rocks. 1150-2300 feet. #54,56,188.

Lophocoleaceae

*Chiloscyphus pallescens (Ehrh.) Dumort. Jackson Co., N. C. (Blomquist, 1936).

*Geocalyx graveolens (Schrad.) Nees Transylvania Co., N. C. (Blomquist, 1936).

*Harpanthus scutatus (Web & Mohr.) Spruce Jackson Co., N. C. (Blomquist, 1936 and Schuster #45091).

Lophocolea bidentata (L.) Dum. Below the Upper Falls. On the root of a Rhododendron sp. 2000 feet. #39.

Lophocolea cuspidata (Nees) Limpr. Below the Upper Falls. Moist humus over a rock. 2000 feet. #49.

*Lophocolea heterophylla (Schrad.) Dumort. Above the Lower Falls. Over rocks in the woods. 7-26-2978 (Hicks #8383).

*Lophocolea muricata (Lehm.) Nees Below the Lower Falls. On rocks. (Hicks #8551) and Below the Lower Falls, near Jocassee. Base of a Yellow Birch. (Schuster)

Lophoziaceae

*Lophozia bicrenata (Schmid.) Dumort. Near Jocassee, Oconee Co., S. C. (Schuster).

Plagiochilaceae

Plagiochila appalachiana H. Inoue Below the Upper Falls, Lake Jocassee. Over rocks. 1120-1250 feet. #38,53,137,141,146,150,164,165,169,176,177,190,197,198.

Plagiochila asplenioides subsp. porelloides (Torrey ex Nees) Schust. Upper Falls, Corbin Creek, Lake Jocassee. Over rocks and soil. 1120-2680 feet. #81,114, 142,156,157,172.

Radulaceae

Radula australis Aust. Upper Falls, Lake Jocassee. Bark of trees, wet rocks, rock outcrops. 1175-2500 feet. #54,70,83,1655.

Radula complanata subsp. complanta (L.) Dumort. Oconee Co., S. C. (Schuster and Anderson #7253).

Radula mollis Lindenb. & G. Near the mouth of the gorge, northeast of Jocassee, Oconee Co., S. C. (Schuster #33568), below the Lower Falls (Schuster #40900c, 40899, 40939a), along a small tributary to the Whitewater, 0.5 mile below the Lower Falls (Hicks #8379).

Radula obconica Sulliv. Below the Upper Falls, Lake Jocassee. Bark of trees, rocks. 1120-2000 feet. #32,237,162,297.

Radula sullivantii Aust. Below the Upper Falls, Upper Falls, Lake Jocassee. Over rocks, soil. 1110-2650 feet. #35,84,89,150,154,158,173,196.

Radula tenax Lindb. Upper Falls, Below the Upper Falls, Lake Jocassee. Rock outcrops, bark of trees. 1100-2350 feet. #36,53,133,140,142,159,162,169.

Scapaniaceae

*Diplophyllum andrewsii Evans Near the Upper Falls. (Schuster #29003), ca. 0.5 mile below the Lower Falls, Oconee Co., S. C. (Schuster #33566).

Diplophyllum apiculatum (Evans) Steph. Above the Upper Falls, Corbin Creek, Upper Falls, Lower Falls. Wet rocks, moist soil. 1200-2760 feet. #8,87,104,108,116,130.

*Diplophyllum taxifolium (Wahl.) Dum. Upper Falls. Over rocks. (Hicks #8021).

Scapania nemorosa (L.) Dum. Upepr Falls, Below the Upper Falls, Corbin Creek. Wet rocks, soil, wood. 1120-2750 feet. #28,42,48,57,58,59,69,72,74,76,77,80,110,117,120,122,126,129,132,138,157,160,168,194.

Scapania undulata (L.) Dum. Corbin Creek, Lower Falls. Over wet rocks. 1200-2600 feet. #18,119.

TRICHOCOLEACEAE

Trichocolea tomentella (Ehrh.) Dum. Upper Falls. Over rocks. 2100 feet. #103, over rocks in the spray of Upper Falls. (Hicks #8029).

B. Occurrence of Hepatics

1. Calculation of Species Occurrence

The common methods of calculating vegetative frequency or occurrence are generally unsuitable for the bryophytes. This is due, in part, to the random sampling methods used when collecting bryophyte specimens. For use in this study, the author devised a method of calculating the gorge relative occurrence and the site relative occurrence (Figure 7) for all the species of liverworts collected from the Whitewater River gorge. Gorge relative occurrences are summarized in Table 1. Gorge and site relative occurrences, along with species substrate preferences are summarized in Tables 2-7 in the Appendix.

$$\text{Gorge Relative Occurrence} = \frac{\text{total number of times a species was collected from gorge}}{\text{total number of specimens collected from gorge (314)}} \times 100$$

$$\text{Site Relative Occurrence} = \frac{\text{total number of times a species was collected at a study site}}{\text{total number of specimens collected at that study site}} \times 100$$

Figure 7. Equations for the Calculation of Gorge and Site Relative Occurrence.

2. Table of Gorge Relative Occurrence.

Table 1. Relative Occurrence of Hepatics in the Whitewater River Gorge

Species	Gorge Relative Occurrence
Conocephlalum conicum	0.95
Dumortiera hirsuta	0.95
Aneura pinguis	0.32
Riccardia chamedryfolia	0.32
Riccardia multifida	1.26
Pallavicinia lyellii	0.95
Pellia epiphylla	2.85
Pellia neesiana	0.63
Metzgeria conjugata	2.22
Metzgeria crassipilis	1.89
Metzgeria furcata	0.32
Metzgeria leptoneura	0.32
Metzgeria temperata	0.95
Odontoschisma denudatum	0.32
Odontoschisma prostratum	2.22
Blepharostoma trichophyllum	0.32
Calypogeia fissa	2.53
Calypogeia muelleriana	4.75
Calypogeia peruviana	0.32

Table 1 (cont.) Relative Occurrences of Hepatics in the Whitewater River Gorge

Species	Gorge Relative Occurrence
Calpogeia sullivantii	0.32
Cephalozia biscuspidata	0.95
Cephalozia connivens	1.26
Cephalozia lununlifolia	0.32
Nowellia curvifolia	1.89
Frullania brittoniae	0.32
Frullania plana	1.58
Frullania squarrosa	1.26
Frullania tamarisci subsp. asagrayana	0.63
Jubula pennsylvanica	7.28
Marsupella emarginata	0.95
Jungermannia lanceolata	0.63
Solenostoma crenuliformis	3.16
Solenostoma gracillimum	0.63
Solenostoma hyalinum	0.32
Solenostoma obscurum	1.58
Cololejeunea bibblecomiae	0.63
Drepanolejeunea appalachiana	0.32
Harpalejeunea ovata	1.89

Table 1 (cont.) Relative Occurrences of Hepatics in the Whitewater River Gorge

Species	Gorge Relative Occurrence
Lejeunea laetevirens	1.58
Lejeunea lamarcerina subsp. gemminata	0.63
Lejeunea ruthii	0.95
Lejeunea ulicina subsp. ulicina	0.32
Leucolejeunea clypeata	10.76
Bazzania trilobata	2.53
Microlepidozia sylvatica	3.48
Lophocolea bidentata	0.32
Lophocolea cuspidata	0.32
Plagiochila appalachiana	4.43
Plagiochila asplenioides subsp. porelloides	1.89
Plagiochila sharpii	0.32
Plagiochila sullivantii	0.32
Plagiochila virginica var. carolinana	0.32
Porella pinnata	2.22
Porella platyphylla	0.95
Radula australis	1.26
Radula obconica	1.26
Radula sullivantii	2.53

Table 1 (cont.) Relative Occurrences of Hepatics in the Whitewater River Gorge

Species	Gorge Relative Occurrence
Radula tenax	2.85
Diplophyllum apiculatum	1.89
Scapania nemorosa	7.59
Scapania undulata	0.63
Trichocolea tomentella	0.323

3. Discussion of Site Relative Occurrence

Twenty-five species of liverworts were collected from the study site number three, which encompassed the west side of the Whitewater River gorge, adjacent to the Upper Falls, and the area around the base of the Falls. Scapania nemorosa (L.) Dum., with a relative occurrence of 16.66%, was the most frequently collected species at this study site. This species was also found on a variety of substrates, from bark to humus and soil. Calypogeia muelleriana (Schiffn. K. Muell.) was rather abundant in this part of the gorge with a site relative occurrence of 11.11%. Other species that were frequently collected here include, Pellia epiphylla (L.) Carda, Metzgeria crassipilis (Lindb.) Evans, Radula australis Aust., Frullania plana Sull., and Metzgeria conjugata Lindb., (Table 4.)

This particular site contained a wide variety of microenvironments suitable for hepatic populations. An Oak-Hickory-Pine type forest was the most extensive community in this area. The forest provided some prime habitat for such xerophytes as Porella platyphylla (L.) Pheiff. and Metzgeria furcata (L.) Dum. Nearer the river, the forest community graded into a Mixed Mesophytic type and the more mesic species such as Diplophyllum apiculatum

(Evans) Steph. and Calypogeia muelleriana (Schiffn.) K. Muell. became more abundant. Species that can tolerate both shade and light, such as Nowellia curvifolia (Dicks.) Mitt., and Cololejeunea biddlecomiae (Aust.) Evans and the more shade tolerant Metzgeria conjugata Lindb. were also found in this forested area. Aneura pinguis (L.) Dum., Porella pinnata L. Trichocolea tomentella (Ehrh.) Dum., and Jubula pennsylvanica (Steph.) Evans were collected from wet rocks around the base of the Upper Falls. This area is kept constantly cool and moist from the mist and the constant breeze that is generated by the force of the water from the Upper Falls falling 125 meters down into the river gorge. Several Appalachian endemics were collected in this area, including Cololejeunea biddlecomiae (Aust.) Evans, Frullania brittoniae Evans, Radula sullivantii Aust., and Radula tenax Lindb.

A total of twenty-five species of hepatics were collected at study site number four, located approximately 610 meters downstream the Upper Falls on the Whitewater River. Most specimens were scraped from the rocks in the river and along the riverbank, and from the bases or trunks of the trees that line both sides of the river. Jubula pennsylvanica (Steph.) Evans had the highest site relative occurrence, 17.14% (Table 5). Specimens of this species were collected most often from the rocks in the riverbed subjected to frequent inundations from the rushing river. A few collections were made from the Mixed Meophytic type forest nearest the river. Species collected at study site number four that are common to the Mixed Mesophytic type of community include Calypogeia muelleriana (Schiffn) K. Muell., Cephalozia connivens (Dicks.) Lindb., and the shade tolerant endemic Cololejeunea biddlecomiae (Aust.) Evans. All three of these species were collected from the surfaces of decaying logs. Several other species, generally common to this region of the Appalachians, were collected quite often at this study site. The endemic Leucolejeunea clypeata (Schwein.) Evans and Scapania nemorosa (L.) Dum. had a site relative occurrence of 8.57%. Bazzania trilobata (L.) Gray had a site relative occurrence of 5.71%. The hygrophyte, Porella pinnata L. was collected 2.86% of the time at this particular site and was commonly found on wet rocks in the river. Twelve endemics were collected in this study area. These species include Cololejeunea biddlecomiae (Aust.) Evans, Drepanolejeunea appalachiana Schust., Lejeunea lamacerina subsp. gemminata Schust., Leucolejeunea clypeata (Schwein.) Evans, Plagiochila appalachiana H. Inoue, Plagiochila sharpii Blomq., Porella pinnata L., Radula obconica Sull, Radula sullivantii Aust., Radula tenax Lindb., Solenostoma crenuliformis

(Aust.) Steph., and Solenostoma obscurum (Evans) Mitt. The strict Appalachian endemic, Herberta adunca subsp. tenuis Evans has been reported from below the Upper Falls by Schuster. Leucolejeunea unciloba (Lindb.) Evans, also collected by Schuster from this area of the gorge, is the only species with any tropical affinities that has been noted from this particular study site.

Collection site number five, which included the area around the Lower Falls of the Whitewater River, yielded nineteen different liverwort species. The Appalachian endemic, Leucolejeunea clypeata (Schwein.) Evans, was collected more often at site number five than at any other study site. Here, the species had a site relative occurrence of 26.47% (Table 6). It was most commonly found on moist rocks and the bark of trees. Calypogeia muelleriana (Schiffn.) K. Muell., with a site relative occurrence of 11.76% was collected on a variety of substrates, including moist soil, rocks, and tree bark. Harpalejeunea ovata (Hook.) Schiffn., which is normally abundant throughout the Appalachians, was collected more frequently in this area than at any other study site with a site relative occurrence of 8.82% (Table 6). Marsupella emarginata (Ehrh.) Dum. and Microlepidozia sylvatica (Evans) Joerg. shared a site relative occurrence of 5.88% at site number five and were most commonly collected on moist humus, soil, or rocks.

The Mixed Mesophytic forest found along the steep west side of the gorge, adjacent to the Lower Falls, and study site number five, provided habitats for some of the more mesophytic species such as *Blephrostoma trichophyllum* (L.) Dum. This is a shade or light tolerating species, as is *Frullania tamarisci* subsp. *asagrayana* (Mont.) Hatt., which was collected from the bark of an Oak tree near the base of the Falls. *Lejeunea laetevirens* Nees & Mont. was the only species collected at the Lower Falls with any tropical affinities. The author expected to find more tropical disjunct species in this area, considering its proximity to Lake Jocassee and the protected nature of the area. *Radula mollis* Lindenb. & G., collected by Schuster and Hicks, is the only other liverwort with tropical affinities that has been reported from this general area of the Lower Falls. Eleven species of tropical liverworts have been reported from the Lake Jocassee area. The absence of many of these liverworts from the Lower Falls may be due to the difference in elevation between the two sites. Quite possibly, those tropical species collected at Lake Jocassee around 335 meters reach their maximum elevation in that general area.

Fifteen different species of liverworts were collected from the study site number one, located along a section of Corbin Creek, a tributary to the Whitewater River. This area was very protected, surrounded by thick stands of Rhododendron sp. as well as extremely dense herbaceous vegetation throughout the summer months. The Mixed Mesophytic Cove-Type forest on this ridge keeps the creek in constant deep shade, warranting the use of a flashlight in order to investigate the area for liverwort populations. Some of the more common, mesic, and shade tolerant, species were collected here. Scapania nemorosa (L.) Dum had a site relative occurrence of 23.33% (Table 2) and Nowellia curvifolia (Dicks.) Mitt. had a site relative occurrence of 13.33% at site number one. Calypogeia fissa (L.) Raddi and the endemic Jubula pennsylvanica (Steph.) Evans each had site relative occurrences of 10%. Microlepidozia sylvatica (Evans) Joerg. and the Appalachian endemic, Diplophyllum apiculatum (Evans) Steph. were collected 6.66% of the time. Wet rocks in the creek bed provided substrates for many of these species. No species with tropical affinitites were collected in this study area. Frullania plana Sull. and Solenostoma crenuliformis (Aust.) Steph. are other endemics that were collected at Corbin Creek.

Fourteen liverwort species were collected at study site number two, above the Upper Falls. Specimens were taken from various places along the west river bank, approximately 305 meters from the crest of the Falls. Species such as Riccardia multifida (L.) S. Gray, Dumortiera hirsuta (Sw.) Nees, and Metzgeria leptoneura Spruce were collected from rocks in a very small spring flowing into the river and from a wet, undercut area in the side of the river bank. The whole area is shaded by tall Hemlocks and is quite humid from its proximity to the river and spring. The mesophyte, Odontoschisma denudatum (Nees) Dum. was collected from around the bases of several of the hemlocks. Odontoschisma prostratum was collected most often at study site number two, with a relative occurrence of 18.75% (Table 3). This is the only species with tropical affinities collected at this study site. Diplophyllum apiculatum (Evans) Steph. and Leucolejeunea clypeata (Schwein) Evans are the only two endemics that were collected above the Upper Falls.

Study site number six contained the greatest number of liverwort species. This site was located at the confluence of the Whitewater River and Lake Jocassee. A total of 40 different species was collected there.

Many species of liverworts are substrate specific. The abundant rocks and various trees in study area number six provided suitable substrates for bryophyte populations. Many of the rocks, in and along the edges of the river at study site number six were subject to constant or periodic splashing and spraying from the river. Hygrophytes, such as Porella pinnata L., are common to these microhabitats. The shaded rock outcrops along the edges of the river and the rocks along the river bed, receiving direct sunlight for most of the day, provided substrates for those species which are tolerant of a wide range of light intensities such as, Frullania tamarisci subsp. asagrayana (Mont.) Hatt. and Leucolejeunea sp. (Schuster, 1957). Leucolejeunea clypeata (Schwein.) Evans and Lejeunea ruthii (Evans) Schust. were often collected from the bark of trees situated along the riverbank. Nowellia curvifolia (Dicks.) Mitt. and Odontoschisma prostratum (Sw.) Trev. were characteristically collected most often from moist, decaying wood.

The Appalachian endemic, Leucolejeunea clypeata (Schwein.) Evans, had the highest site relative occurrence (14.39) at study site number six followed by, Plagiochila appalachiana H. Inoue, (9.09) Jubula pennsylvanica (Steph.) Evans, (8.33) Radula tenax, Lindb. (5.30), Solenostoma crenuliformis (Aust.) Steph. (5.30) (Table 7). The greatest diversity of species was also noted at this site. Fourteen species collected from this study area are classified as Appalachian endemics. Those endemics include: Frullania tamarisci subsp. asagrayana (Mont.) Hatt., Lejeunea lamacerina subsp. gemminata Schust., Metzgeria crassipilis (Lindb.) Evans, Plagiochila appalachiana H. Inoue, Porella pinnata L., Calypogeia sullivantii Aust., Frullania plana Sull., Lejeunea ruthii (Evans) Schust., Leucolejeunea clypeata (Schwein.) Evans, Radula australis Aust., Radula obconica Sull.,K. Radula tenax Lindb., Solenostoma crenuliformis (Aust.) Steph., and Solenostoma obscurum (Evans) Mitt. Other endemics which were previously collected in this general area by Schuster, but were not collected during this study, include Leucolejeunea conchifolia (Evs.) Evs., Plagiochila undata Sulliv., and Solenostoma fossombronioides (Aust.) Schust. Two narrow endemics, Plagiochila sullivantii Gott. and Radula sullivantii Aust. were also collected, by the author, at this site. Schuster reports two other narrow endemics from this area. These are Cheilolejeunea evansii (M. S. Tayl.) Schust. and Nardia lescurii (Aust.) Underw. Only three species with tropical affinities were collected at the Jocassee site. These include

Odontoschisma prostratum (Sw.) Trev., Calypogeia peruviana Nees & Mont., and Lejeunea laetevirens Nees & Mont. Eight more species with some tropical affinities have been reported from this general area by Schuster. These species include Cheilolejeunea myriantha (Nees & Mont.) Schust., Cololejeunea cardiocarpa (Mont.) Schust., Lejeunea ulicina subsp. bullata (Tayl.) Schust., Leucolejeunea unciloba (Lindenb.) Evs., Plagiochila ludovicina Sulliv., Radula mollis Lindenb. & G., Rectolejeunea maxonii Evs., and Lophocolea muricata (Lehm.) Nees.

The elevation at the Lake Jocassee study site, which is approximately 274-305 meters above sea level, may be an additional factor, besides substrate, which has contributed to the number and diversity of the liverworts collected there. Plagiochila undata Sulliv., is a species that is commonly found along the southeastern Coastal Plain and the inner Piedmont of the eastern United States up to the lowest elevations of the southern Appalachians. Radula australis Aust. is normally restricted to the swampy forests of the outer Coastal Plain of the southeastern United States, but has disjunct populations in the escarpment region. Both of these species have been reported from the Lake Jocassee area, and reach the upper limits of their elevational ranges here. _Tritomaria exsecta_ (Schrad.) Loeske is commonly found at higher elevations in the southern Appalachians, but has also been collected in this area, possibly reaching its lower elevational limits here. This evidence indicates that somewhat of a transitional zone or ecotone exists in the Lake Jocassee area.

VI. DISCUSSION

A. Hepatic Ecology

A large majority of the Hepatics have narrow and sharply defined occurrences which have been determined by climate, chemical and physical factors of the microhabitat and substrate and by competition with other species (Schuster, 1957).

Generally, the bryophytes differ from the seed plants in their ecological tolerance. Bryophytes may occupy hard surfaces, like bark or rocks, that cannot be invaded by most seed plants. Bryophytes also colonize soil surfaces. Some species are confined to surfaces exposed to splashing or rapidly moving water (Schofield, 1985). This narrowly circumscribed occurrence gives the Hepaticae definite value as indicators of microedaphic conditions and microclimates with limited value as indicators for macroclimate and macroedaphics (Schuster, 1957). A knowledge of bryophyte floristics is often useful in characterizing a site. In some areas it is possible to state fairly accurately the structure and productivity of the vascular plant community when only the bryophyte vegetation is documented. Collections of hepatics made from the Whitewater River gorge indicate that this particular gorge is a refuge for some unique plants and important microclimates and microhabitats.

The ecological amplitude of many hepatic species varies from region to region. Generally, those species nearest their center of distribution occur under a very wide and varied set of conditions (Schuster, 1957). The best example of a species from the Whitewater River gorge exhibiting this phenomenon is *Leucolejeunea clypeata* (Schwein.) Evans. This species is extremely abundant and is commonly found on a wide variety of substrates. *L. clypeata* has been collected from such zeric substrates as the bark of various trees and dry rock surfaces as well as mesic or even hygric substrates such as moist humus and wet rock surfaces. This species had a gorge relative occurrence of 10.76% (Table 1) which makes it the most frequently collected species throughout all of the study sites in the Whitewater gorge. It is the only member of its genus that is found beyond those areas devastated by Pleistocene glaciation (Schuster, 1957). To the north, *Leucolejeunea clypeata* (Schwein.) Evans is exceptionally rare. According to Schuster (1957) a species at the periphery of its range tends to have a much more sharply circumscribed ecological range, and is usually restricted, in occurrence, to one or two sites.

Several of the tropically disjunct species of liverworts from the Whitewater River gorge also exhibit this ecological characteristic. One example is Calypogeia peruviana Nees & Mont. This neotropical species is restricted to scattered locations along some of the most isolated, protected stream banks in the southern Appalachian gorges, usually below 762 meters.
It occurs abundantly from Brazil to Peru, to Columbia and Venezuela, north to the West Indies and Mexico (Bischler, 1963). Another example is Lophocolea muricata (Lehm.) Nees, which is another rare disjunct in the escarpment gorges of the Southern Appalachians. This species is widespread in the Southern Hemisphere and in temperate and tropical regions but is restricted to a very few sites in the Southeastern escarpment area. Here, it occurs in small quantities among other bryophytes.

It has become the concern of some biologists that the creation of Lake Jocassee has had adverse effects on the flora of that region. Approximately 8 kilometers of the lower end of the Whitewater River gorge was drowned by Lake Jocassee. Some species of liverworts, most of which were collected by Schuster (1966-1980), may have had critical populations destroyed by the lake. Several species were not collected during this study and have not been reported from the Jocassee area since the lake was completed.

Cheilojejeunea evansii (M. S. Tayl.) Schust. was collected by Schuster several years before the completion of Lake Jocassee in 1973. He reports this species from South Carolina, just above the mouth of the Whitewater River gorge and several points below the Lower Falls. This species is endemic to only a small region in Pickens and Oconee Counties, South Carolina and Jackson and Transylvania Counties, North Carolina. It is said to occur predominately in deep gorges, chiefly in the region between the escarpment Plateau and the adjacent Piedmont. Therefore, it is possible that Lake Jocassee has destroyed some extremely critical populations of this restricted endemic.

Lophocolea muricata (Lehm.) Nees is a rare disjunct in the escarpment gorges. It is found from northern South America to Central America. Schuster reports having collected specimens of L. muricata (Lehm.) Nees from a site near the town of Jocassee, which is now flooded by Lake Jocassee. Rectolejeunea maxonii Evs. is another tropical disjunct that Schuster collected 4.8 kilometers northwest of the town of Jocassee. Rare populations of this species, as well as limited populations of

Cololejeunea _cardiocarpa_ (Mont.) Schust., may have been destroyed by the lake. _C._ _cardiocarpa_ (Mont.) Schust. has been reported, by Schuster, from the lower end of the Whitewater River gorge, approximately 3.2 kilometers above the former town of Jocassee.

Finally, _Cephalozia_ _bicuspidata_ subsp. _otaruensis_ (Steph.) Hatt., which is commonly overlooked for _Cephalozia_ _bicuspidata_ (L.) Dumort., is widespread in Japan, but is only known in the United States from a few sites in the southern Appalachian gorges. Schuster reported a collection of this particular subspecies from the Thompson River, 1.6 to 3.2 kilometers above the Whitewater River in Oconee County, South Carolina. This site is now covered by the waters of Lake Jocassee.

B. Distribution Patterns

The distribution patterns of the bryophytes may be useful in explaining and interpreting the origins and relationships of past vegetation and environments throughout the world (Anderson, 1963). According to Schofield (1985) the study of bryophyte distributions has been somewhat hampered by inadequate documentation, and is often a reflection of the number of experienced collectors and researchers.

Compared to the seed plants, many bryophyte families and genera show an extremely wide range, independent of climatic differences. Some genera are more richly represented in the Northern Hemisphere than elsewhere, suggesting that they originated in north temperate regions. Very wide distributions suggest that the genera are ancient (Schofield, 1985). Liverworts collected from the Whitewater River gorge exhibiting a predominantly Northern pattern of distribution include:

Jamesoniella autumnalis (DeCand.) Steph.

Cephalozia connivens (Dicks.) Lindb.

Marsupella sphacelata fo. *media* (G.) Schust.

Scapania undulata (L.) Dum.

Porella platyphylla (L.) Pfeiff.

Blepharostoma trichophyllum (L.) Dum.

Geocalyx graveolens (Schrad.) Nees.

Radula complanata subsp. _complanata_ (L.) Dumort.

Riccardia latifrons Lindb.

Solenostoma hyalinum (Lyeli) Mitt.

Several other species are classified as oceanic or suboceanic within the Northern pattern of distribution. The majority of these populations are distributed along the outer margins of those continents which border the Atlantic Ocean and are generally absent from the interior of these continents. Oceanic or suboceanic species from the Whitewater River gorge include:

Harpalejeunea ovata (Hook.) Schiffn.

Lejeunea ulcina subsp. _ulcina_ (Tayl.) Tayl. ex G.L & N.

Microlepidozia sylvatica (Evans) Joerg.

Calypogeia fissa (L.) Raddi

Nowellia curvifolia (Dicks.) Mitt.

Trichocolea tomentella (Ehrh.) Dum.

Bazzania trilobata (L.) S. F. Gray

Scapania nemorosa (L.) Dum.

A number of hepatics collected from the Whitewater River gorge have been classified as Holaractic by Schuster (1969-1980). According to Schofield (1985) the Holarctic region encompasses much of the Northern Hemisphere and includes most of North America, Europe, and Asia. This area has a remarkable uniformity in the bryoflora, even at the species level. Those species found throughout the temperate regions of the Holarctic include:

Harpanthus scutatus (Web. & Mohr.) Spruce

Lophocolea heterophylla (Schrad.) Dumort.

Lophocolea cuspidata (Nees.) Limpr.

The species collected from the Whitewater River gorge that are mainly distributed throughout the cooler regions of the Holarctic include:

Cephalozia lunulifolia (Dum.) Dum.

Diplophyllum taxifolium (Wahl.) Dum.

Marsupella emarginata (Ehrhl.) Dum.

Some of the hepatics collected in the Whitewater River gorge have been reported from many locations within the Holarctic range and are therefore considered to be widespread throughout this region. These species are:

Lophozia bicrenata (Schmid.) Dumort.

Solenostoma gracillimum (Sm.1) Schust.

Chiloscyphus pallenscens (Ehrh.) Dumort.

Jungermannia lanceolata L.

The most widespread taxon of Plagiochila, with a nearly Holarctic range, found in Whitewater River gorge was,

Plagiochila asplenoides subsp. porelloides (Torrey ex Nees.) Schust.

Those species reported from North America, Europe, Asia collectively by Schuster (1969-1980) and by Frye and Clark (1937-1947) include:

Calypogeia neesiana (Mass. & Carest.) K. Muell.

Pellia epiphylla (L.) Corda

Pellia neesiana (Gott.) Limpr.

A few bryophyte species are cosmopolitan. The following species have been reported from all the continents except Antarctica:

Dumortiera hirsuta (Sw.) Nees.

Metzgeria conjugata Lindb.

Metzgeria leptoneura Spruce

Metzgeria furcata (L.) Dum.

The following species are nearly cosmopolitan, found on all the continents except Australia and Antarctica:

Riccardia multifida L. S. Gray

Pallavicinia lyelli (Hook.) Carruth.

Aneura pinguis (L.) Dum.

Another species with a near cosmopolitan distribution, reported from most major continents except Europe, Antarctica, and Australia is:

Frullania squarrosa (R. B. N.) Nees.

A few species of hepatics from the Whitewater River gorge show a wide distribution in the Northern Hemisphere and reappear, sometimes locally, in temperate portions of the Southern Hemisphere. This type of distribution is referred to as bipolar by Schofield (1985). Bipolar species from the Whitewater River include:

Cephalozia bicuspidata (L.) Dum.

Conocephalum conicum (L.) Lindb.

Odontoschisma denudatum (Nees.) Dum.

A number of the liverworts reported from the Whitewater River gorge have tropical and subtropical affinities. Those hepatics with ranges extending from South and Central America northward into the eastern and southeastern parts of North America are considered Neotropical species. Neotropical species represented in the Whitewater River gorge are:

Radulla mollis Lindenb. & G.

Rectolejeunea maxonii Evs.

Odontoschisma prostratum (Sw.) Trev.

Neotropical species with restricted or disjunct occurrences in the Escarpment region of the Southern Appalachians include:

Lejeunea laetevirens Nees. & Mont.

Cheilolejeunea myriantha (Nees & Mont.) Schust.

Lejeunea ulicina subsp. *bullata* (Tayl.) Schust.

Plagiochila _ludoviciana_ Sulliv.

Calypogeia _peruviana_ Nees & Mont.

Two Neotropical species, reported also from Africa, or the Paleotropics, are also reported from the Whitewater River gorge. These species are:

Cololejeunea _cardiocarpa_ (Mont.) Schust.

Leucolejeunea _unciloba_ (Lindenb.) Evs.

A rare disjunct liverwort in the escarpment of the Southern Appalachians with nearly Pantropical distribution; being found throughout both the Old and New World tropics is:

Lophocolea _muricata_ (Lehm.) Nees

An interrupted pattern of world distribution is shown by a number of bryophytes. A few species of liverworts from the Whitewater River gorge are reported from Japan and the southern Appalachians of eastern North America only. Disjunctions between eastern Asia and eastern North America appear to be ancient, according to Schofield (1985). These disjunct species from the Whitewater include:

Diplophyllum _andrewsii_ Evans

Metzgeria _temperata_ Kuwah.

Solenostoma _pyriflorum_ Steph.

Schuster (1982) refers to the phenomenon of endemism as the "strict occurrence of a taxon limited to a small, homogeneous geographic area." For eastern North America, mainly east of the Appalachian Mountains, no genera of hepatics are listed as endemic, while about 20% of the species appear to be endemic (Schofield, 1985). Approximately 56% of the hepatic species reported from the Whitewater River gorge are endemic. Endemism in the bryoflora of most areas is related to three features: (1) the length of time during which the region has been available for colonization, (2) environmental diversity, especially the availablity of atmospheric moisture, and (3) length of time in comparative isolation (Schofield, 1985). The following group of hepatics are considered to be broad Appalachian endemics. These liverworts are predominantly Appalachian in range. Many are distributed in other parts of eastern North America, but are mainly Appalachian.

Calypogeia sullivantii Aust.

Cololejeunea biddlecomiae (Aust.) Evans

Diplophyllum apiculatum (Evans) Steph.

Frullania brittoniae Evans

Frullania plana Sull.

Frullania tamarisci subsp. asagrayana (Mont.) Hatt.

Jubula pennsylvanica Steph. Evans

Lejeunea lamacerina subsp. gemminata Schust.

Lejeunea ruthii (Evans) Schust.

Leucolejeunea clypeata (Schwein.) Evans

Marsupella emarginata (Ehrh.) Dum.

Metzgeria crassipilis (Lindb.) Evans

Plagiochila appalachiana H. Inoue

Plagiochila undata Sulliv.

Porella pinnata L.

Radula obconica Sulliv.

Radula tenax Lindb.

Solenostoma crenuliformis (Aust.) Steph.

Solenostoma fossombronioides (Aust.) Schust.

Solenostoma obscurum (Evans) Mitt.

Herberta adunca subsp. tenuis (Evans) Miller & Scott

Radula australis Aust.

Calypogeia muelleriana (Schiffn.) K. Muell.

The species of hepatics distributed in a limited area of the southeastern United States are termed narrow endemics of the southern Appalachians. The narrowly endemic species from the Whitewater River gorge that have been reported solely from the escarpment region are:

Leucolejeunea conchifolia (Evs.) Evs.

Plagiochila virginica var. caroliniana Schust.

Cheilolejeunea evansii (M. S. Tayl.) Schust.

Drepanolejeunea appalachiana Schust.

Plagiochila caduciloba Blomquist.

Marsupella paroica Schust.

Nardia lescurii (Aust.) Underw.

Plagiochila euryphyllon subsp. *echinata* (Schust.) H. Inoue

Plagiochila sharpii Blomquist

Plagiochila sullivantii Gott.

Plagiochila sullivantii var. *spinigera* Schust.

Radula sullivantii Aust.

C. Historical Bryogeography

The current distribution patterns of the species of hepatics from the Whitewater River gorge may support the theory that their distribution patterns resulted from a previous continuous range that was disrupted by continental separation (Sharp, 1984). *Diplophyllum andrewsii* Evans and *Solenostoma pyriflorum* Steph. are reported from the southern Appalachians and Japan only and may represent part of the Arcto-Tertiary bryoflora. Both *Porella platyphylla* (L.) Pfeiff., which is widespread in northern temperate regions, and *Calypogeia fissa* (L.) Raddi, which is chiefly "Atlantic" in distribution may be remnants of the Arcto-Tertiary forest. Still other species are distributed worldwide. *Metzgeria conjugata* (Lindb. and *Dumortiera hirsuta* (Sw.) Nees have been reported from all continents, except Antarctica. *Riccardia multifida* L. S. Gray is found on all the continents except Australia and Antarctica.

Sharp (1941) also discusses the possibility that glaciation may have helped increase the number of species of bryophytes in the southern Appalachians. As the glaciers spread, some of the more tolerant northern species may have migrated southward and eventually met one of three fates. Some of these species may have retreated northward as the glaciers retreated, leaving no record in the south. Other species may have developed a wide range of tolerances and now have continuous ranges to the north, such as Riccardia chamedryfolia (With.) Grolle and Blepharostoma trichophyllum (L.) Dum. Still, other disjunct northern species may have persisted in the south. Diplophyllum apiculatum (Evans) Steph. is endemic to eastern North America and ranges from the mid-south to areas bordering the glaciated regions in the north. Isolated populations of this species are also reported from Quebec. Glacial advances may have pushed populations to the south and eliminated once continuous ranges. Northward migration of some species was also halted by the ice-dammed rivers of the north. This may have resulted in the limited ranges shown by some hepatics. Plagiochila sullivantii G. ex. Evs., a narrow endemic of the southern Appalachians, reported from West Virginia, Virginia, and North Carolina may be a relict of the old Tertiary forest of the southern Appalachians (Schuster, 1980).

The lowering of world temperatures, before and during the glacial period, had a permanent effect on some of the warm temperate and subtropical species of bryophytes in the southern Appalachians. The present flora was impoverished by the extinction of some of the warm temperate and most of the subtropical species during the rigors of the Pliocene and Pleistocene, if not in earlier times. Only those species remain today whose genetic constitution permitted them to survive under those conditions (Sharp, 1970). <u>Calypogeia</u> <u>peruviana</u> Nees & Mont. represents a neotropical species which reaches its northern limit in some of the protected areas of the southern Appalachians. <u>Lejeunea</u> <u>laetevirens</u> Nees & Mont. is another neotropical species with disjunct populations in the southeastern escarpment region. Several investigators (Sharp 1939, 1941; Cain 1943; Braun 1950) agree that some post-glacial migration into the Blue Ridge region from the south did occur (Billings and Anderson, 1966).

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APPENDICES

Table 2. Relative Occurrences and Substrate Preferences - Corbin Creek

Study Site: Corbin Creek	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Calypogeia fissa	10.00	2.53	rocks
Calypogeia muelleriana	3.33	4.75	rocks
Cephalozia connivens	3.33	1.26	wet rocks
Diplophyllum apiculatum	6.66	1.89	rocks
Frullania plana	3.33	1.58	rocks
Jubula pennsylvanica	10.00	7.28	rocks
Microlepidozia sylvatica	6.66	3.48	rocks, moist soil
Nowellia curvifolia	13.33	1.89	decaying wood
Pallavicinia lyellii	3.33	0.95	moist soil
Pellia epiphylla	3.33	2.85	wet soil, rocks
Plagiochila asplenoides subsp. porelloides	3.33	1.89	soil on rocks
Scapania nemorosa	23.33	7.59	rocks, wet soil

Table 2 (cont.) Relative Occurrences and Substrate Preferences - Corbin Creek

Study Site: Corbin Creek	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Scapania undulata	3.33	0.63	wet rocks
Solenostoma crenuliformis	3.33	3.16	wet rocks
Solenostoma gracillimum	3.33	0.63	moist soil

Table 3. Relative Occurrences and Substrate Preferences Above the Upper Falls

Study Site: Above the Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Bazzania trilobata	9.37	2.53	moist soil, decaying log
Calypogeia muelleriana	12.50	4.75	wet soil, decaying wood
Diplophyllum apiculatum	6.25	1.89	wet rocks, humus
Dumortiera hirsuta	9.37	0.95	wet rocks, ground
Jubula pennsylvanica	6.25	7.28	wet rocks
Leucolejeunea clypeata	6.25	10.76	bark, rocks
Metzgeria leptoneura	3.12	0.32	wet rocks
Microlepidozia sylvatica	9.37	3.48	moist soil, bark, rotting log
Odontoschisma denudatum	3.12	0.32	soil

Table 3. (cont.) Relative Occurrences and Substrate Preferences Above the Upper Falls

Study Site: Above the Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Odontoschisma prostratum	18.75	2.22	moist soil, bark rotting stump
Pallavicinia lyellii	3.12	0.95	wet soil
Pellia neesiana	3.12	0.63	wet rocks
Radula sullivantii	3.12	2.53	wet rocks
Riccardia multifida	6.25	1.16	wet soil, rocks, roots

Table 4. Relative Occurrences and Substrate Preferences - Upper Falls

Study Site: Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Aneura pinguis	1.85	0.32	wet rocks
Calypogeia muelleriana	11.11	4.75	wet soil, rocks
Cephalozia bicuspidata	1.85	0.95	base of tree
Cololejeunea biddlecomiae	1.85	0.63	bark of tree
Conocephalum conicum	3.70	0.95	wet rocks
Diplophyllum apiculatum	1.85	1.89	wet rocks
Frullania brittoniae	1.85	0.32	bark of tree
Frullania plana	5.55	1.58	dry and damp rocks, soil
Frullania squarrosa	3.70	1.26	dry rock, base of tree
Jubula pennsylvanica	3.70	7.28	rocks, wet humus

Table 4 (Cont.) Relative Occurrences and Substrate Preferences - Upper Falls

Study Site: Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Leucolejeunea clypeata	1.85	10.76	wet rocks
Metzgeria conjugata	5.55	2.22	dry, damp rocks
Metzgeria crassipilis	7.41	1.89	wet, dry rocks, bark of trees
Metzgeria furcata	1.85	0.32	moist soil over rock
Nowellia curvifolia	1.85	1.89	rotting log
Pellia epiphylla	7.41	2.85	wet humus, soil
Plagiochila appalachiana	1.85	4.43	rocks
Plagiochila asplenoides subsp. porelloides	1.85	1.89	soil
Porella pinnata	1.85	2.22	wet rocks
Porella platyphylla	3.70	0.95	dry rock, base of tree

Table 4 (Cont.) Relative Occurrences and Substrate Preferences - Upper Falls

Study Site: Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Radula australis	5.55	1.26	wet rocks, bark of tree
Radula sullivantii	1.85	2.53	rocks
Radula tenax	1.85	2.85	rocks
Scapania nemorosa	16.66	7.59	wet soil, humus, bark
Trichocolea tomentella	1.85	0.32	wet rocks

Table 5. Relative Occurrences and Substrate Preferences - Below the Upper Falls

Study Site: Below the Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Bazzania trilobata	5.71	2.53	dry soil, decaying log
Calypogeia muelleriana	2.86	4.75	decaying log
Cephalozia connivens	2.86	1.26	decaying log
Cololejeunea biddlecomiae	2.86	0.63	decaying log
Drepanolejeunea appalachiana	2.86	0.32	dry rock
Jubula pennnsylvanica	17.14	7.28	wet rock
Lejeunea lamaceriana subsp. gemminata	2.86	0.63	dry rock
Lejeunea ulicina	2.86	0.32	bark of tree
Leucolejeunea clypeata	8.57	10.76	bark, dry rocks

Table 5 (Cont.) Relative Occurrences and Substrate Preferences - Below the Upper Falls

Study Site: Below the Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Lophocolea bidentata	2.86	0.32	root of Rhododendron
Lophocolea cuspidata	2.86	0.32	moist humus
Marsupella emarginata	2.86	0.95	wet rocks
Metzgeria conjugata	2.86	2.22	dry rocks
Microlepodozia sylvatica	2.86	3.48	moist soil
Pellia neesiana	2.86	0.63	moist rock
Plagiochila appalachiana	2.86	4.43	rocks
Plagiochila sharpii	2.86	0.32	dry rock
Porella pinnata	2.86	2.22	wet rock
Radula obconica	2.86	1.26	bark of tree
Radula sullivantii	2.86	2.53	wet rock

Table 5 (Cont.) Relative Occurrences and Substrate Preferences - Below the Upper Falls

Study Site: Below the Upper Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Radula tenax	2.86	2.85	dry rock
Scapania nemorosa	8.57	7.59	wet rock
Solenostoma crenuliformis	2.86	3.16	wet rock
Solenostoma hyalinum	2.86	0.32	wet rock
Solenostoma obscurum	2.86	1.58	wet soil

Table 6. Relative Occurrences and Substrate Preferences - Lower Falls

Study Site: Lower Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Bazzania trilobata	2.94	2.53	humus on rock
Blepharostoma trichophyllum	2.94	0.32	wet humus
Calypogeia fissa	2.94	2.53	moist humus
Calypogeia muelleriana	11.76	4.75	bark, soil, rocks
Cephalozia bicuspidata	2.94	0.95	wet humus
Cephalozia lunulifolia	2.94	0.32	moist humus
Diplophyllum apiculatum	2.94	1.89	moist humus
Frullania squarrosa	2.94	0.95	bark of tree
Frullania tamarisci subsp. asagrayana	2.94	0.63	bark of tree
Harpalejeunea ovata	8.82	1.89	rocks, bark

Table 6 (Cont.) Relative Occurrences and Substrate Preferences - Lower Falls

Study Site: Lower Falls	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Lejeunea ruthii	2.94	0.95	rock
Leucolojeunea clypeata	26.47	10.76	bark, moist rocks
Marsupella emarginata	5.88	0.95	wet rocks
Microlepidozia sylvatica	5.88	3.48	moist humus, soil
Pellia epiphylla	2.94	2.85	wet soil
Plagiochila virginica subsp. caroliniana	2.94	0.32	rocks
Scapania undulata	2.94	0.63	rocks
Solenostoma crenuliformis	2.94	3.16	wet soil
Solenostoma obscurum	2.94	1.58	wet soil

Table 7. Relative Occurrences and Substrate Preferences - Lake Jocassee

Study Site: Lake Jocassee	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Bazzania trilobata	0.76	2.53	soil
Calypogeia fissa	3.03	2.53	wet rock, mud, humus
Calypogeia peruviana	0.76	0.32	wet rock
Calypogeia sullivantii	0.76	0.32	moist soil
Cephalozia bicuspidata	0.76	0.95	moist soil over a rock
Cephalozia connivens	1.51	1.26	decaying wood, soil
Conocephalum conicum	0.76	0.95	rock
Frullani plana	0.76	1.58	soil over a rock ledge
Frullania squarrosa	0.76	1.26	rock outcrop

Table 7 (Cont.) Relative Occurrences and Substrate Preferences - Lake Jocassee

Study Site: Lake Jocassee	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Frullania tamarisci subsp. *asagrayana*	0.76	0.63	bark of tree
Harpalejeunea ovata	2.27	1.89	rocks, trees, soil on rocks
Jubula pennsylvanica	8.33	7.28	wet and dry rocks, soil
Jungermannia lanceolata	1.51	0.63	wet rocks
Lejeunea laetevirens	3.79	1.58	rock outcrops, crevices
Lejeunea lamacerina subsp. *gemminata*	0.76	0.63	rocks
Lejuenea ruthii	1.51	0.95	bark of a tree, rock
Leucolejeunea clypeata	14.39	10.76	bark of trees, rocks

Table 7 (Cont.) Relative Occurrences and Substrate Preferences - Lake Jocassee

Study Site: Lake Jocassee	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Metzgeria conjugata	2.27	2.22	moist soil, rock outcrop
Metzgeria crassipilis	1.51	1.89	rock outcrop
Metzgeria temperata	2.27	0.95	rock outcrop
Microlepidozia sylvatica	2.27	3.48	moist soil
Nowellia curvifolia	0.76	1.89	decaying wood
Odontoschisma prostratum	0.76	2.22	decaying wood
Pallavicinia lyellii	0.76	0.95	wet soil
Pellia epiphylla	2.27	2.85	mud, wet soil over rock
Plagiochila appalachiana	9.09	4.43	rock outcrop
Plagiochila asplenoides subsp. *porelloides*	3.03	1.89	moist rocks, soil

Table 7 (Cont.) Relative Occurrences and Substrate Preferences - Lake Jocassee

Study Site: Lake Jocassee	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Plagiochila sullivantii	0.76	0.32	rock outcrop
Porella pinnata	3.79	2.22	rock, soil over a rock
Porella platyphylla	0.76	0.95	bark of a tree
Radula australis	0.76	1.26	rock outcrop
Radula obconica	2.27	1.26	rock outcrop
Radula sullivantii	3.79	2.53	rock outcrop, soil
Radula tenax	5.30	2.85	rock outcrop, bark of trees
Riccardia chamedryfolia	0.76	0.32	mud
Riccardia multifida	1.51	1.26	wet rocks, soil

Table 7 (Cont.) Relative Occurrences and Substrate Preferences - Lake Jocassee

Study Site: Lake Jocassee	Site Rel. Occurrence	Gorge Rel. Occurrence	Substrate Preference
Scapania nemorosa	3.79	7.59	wet rock, soil, decaying wood
Solenostoma crenuliformis	5.30	3.16	moist rocks, soil
Solenostoma gracillimum	0.76	0.63	wet soil over rocks
Solenostoma obscurum	2.27	1.58	rock, mud on rocks

VITA

Kimberly Sue Oakley Woodrow was born in Durham, North Carolina, January 17, 1958. She is the daughter of Jean H. Dority of Durham and the late Robert I. Oakley. After graduating from Durham High School in 1976, she entered Appalachian State University. She received a Bachelor of Science degree in Biology (Naturalist) from Appalachian State University, August 1980. She began the Master's program at Appalachian State University the same fall and was a graduate assistant in the Biology Department for two years. Her major emphasis of study as a master's student was botany, most specifically bryology.

After a year as the manager of a convenience store, she returned to Appalachian State University in January, 1984 and began the teacher education program. Student teaching was completed at Freedom High School in Morganton, North Carolina where Ms. Woodrow taught freshman biology during the 1985-1986 school year.

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